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NAVAER 10-35-583

PHOTO INDUSTRIAL STUDY NO. 3

THE COKE, IRON & STEEL INDUSTRIES

UNITED STATES FORCES

OFFICE OF THE ASSISTANT CHIEF OF AIR STAFF
INTELLIGENCE HQ., U. S. ARMY AIR FORCES
AND
PHOTOGRAPHIC INTERPRETATION CENTER
DIVISION OF NAVAL INTELLIGENCE, NAVY DEPARTMENT

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BUAER REPRINT—APRIL 1951

PHOTO INDUSTRIAL STUDIES
(ISSUED)

No. 1 Nitrogen
No. 2 Petroleum
No. 3 Coke, Iron and Steel

PHOTO INDUSTRIAL STUDIES
(IN PREPARATION)

Aluminum
Aircraft
Magnesium
Copper
Lead and Zinc
Sugar and Alcohol
Shipbuilding
Munitions


RESTRICTED
PHOTO INDUSTRIAL STUDY NO. 3
THE COKE, IRON AND STEEL INDUSTRIES
UNITED STATES FORCES
OFFICE OF THE
ASSISTANT CHIEF OF AIR STAFF, INTELLIGENCE
HQ., U.S. ARMY AIR FORCES
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NAVY DEPARTMENT
SEPTEMBER 1944
RESTRICTED

Acknowledgment is made to the various offices in the War and Navy Departments and the Army Air Forces, and to government and civilian agencies, industrial concerns, and representatives of foreign governments who have furnished information and assistance in the course of this work. The material thus obtained has been extremely valuable and has added greatly to the content of this production.

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INTRODUCTION

The manufacturing processes of coke, iron, and steel are so completely interdependent that it has been considered desirable to present all three in the same Industrial Study.

Photo Industrial Studies have four aims in relation to photo intelligence:

1. To guide the photo interpreter in the identification of industry;

2. To make available to the photo interpreter all appropriate data on the processes, equipment, and installations used in the industry;

3. To aid the photo interpreter in the assessment of bomb damage, and in the estimation of that damage as related to the operation of the unit under consideration;

4. To assist the photo interpreter in repair progress assessment.

In addition to serving as a photo intelligence aid, these manuals will be found to be of value in the work of P.W.I., C.I., and other intelligence officers.

Photo Industrial Study No. 3 has ten main sections:

The first five sections are divided into chapters dealing with the following subjects:

Importance of Product

Raw Materials

Processes Used
(including buildings and equipment)

The material in this Study has been selected primarily to illustrate the coke, iron, and steel industries under Japanese control. However, the information and photographic coverage over much of the Far East are incomplete at the present time. This problem has been met by supplementing the description of known types of Japanese installations with European and domestic types which there is reason to believe may be used by the Japanese. Coke, iron, and steel are highly standardized industries, and exhibit a great similarity in appearance throughout the world.

Japan has installed good, up-to-date equipment in her plants, which is comparable in quality, if not in quantity to similar equipment in this country. The recent date of Japan's industrialization also means that much of the obsolescent equipment seen in our older industrial areas will be lacking in Japan. On the other hand, the interpreter may come across a few old installations, particularly on the Asiatic mainland, which employ more primitive methods and machinery. He may see manual labor being used in otherwise highly mechanized plants in Japan to perform an operation which would be done by automatic means in this country. There is photographic evidence of this sort of anachronism existing until fairly recently. He will doubtless discover small peculiarities of structural design in Japanese equipment. Nevertheless, the range of probable variation is so small that it is expected that the basic information contained in this Study will enable the interpreter to decipher whatever deviations he may find.

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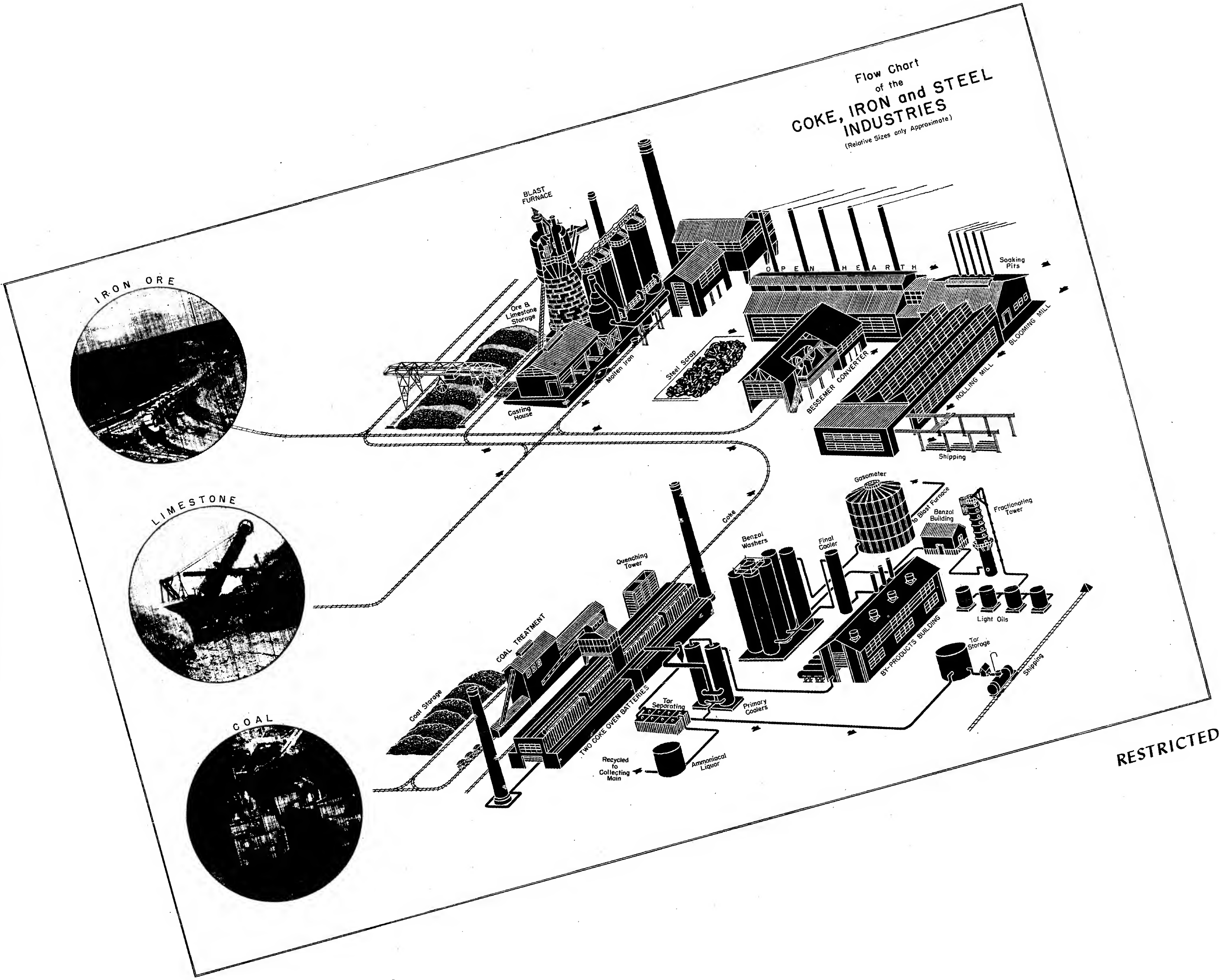

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SECTION I

COKE

Coke Ovens at Yawata, Kyushu
(Photograph reversed)

IMPORTANCE OF PRODUCT

Coke is a solid product obtained by heating coal in an oven in the absence of air. The steel industry uses coke in blast furnace operation as one of the raw materials for making pig iron. Coke has a three-fold use in this smelting process: (1) As a *fuel*, coke provides heat most efficiently and economically; (2) As *a chemical reducing reagent*, coke removes the oxygen in the iron ore; (3) As a *support*, for the huge quantities of material which form a heavy column in the furnace.

Charcoal, which has the same chemical composition and form as coke, was regularly used for these purposes up to a century ago. It is now substituted for coke only under special conditions. Blast furnaces using charcoal are much smaller in size because the weak structure of the charcoal will not support a large column of material in the furnace.

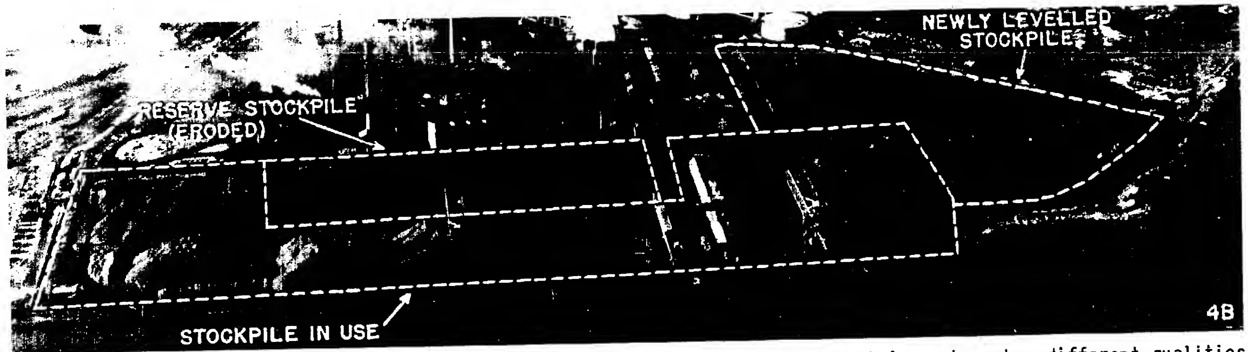
RAW MATERIALS

Coal and fuel gas are the only raw materials needed to produce coke.

COAL

Bituminous, a soft variety of coal, is used for coking. Enormous amounts of coal are consumed daily by an average-sized coke oven. This means that there will normally be huge storage piles which will form one of the recognition features of a coking plant. The stock of coal on hand may be much smaller when a plant is near a mine which feeds it a continuous supply. Limited coal resources or lack of transportation can also reduce the size of reserves at the plant. Under satisfactory conditions, a single battery of coke ovens may store this much coal:


4A



4B

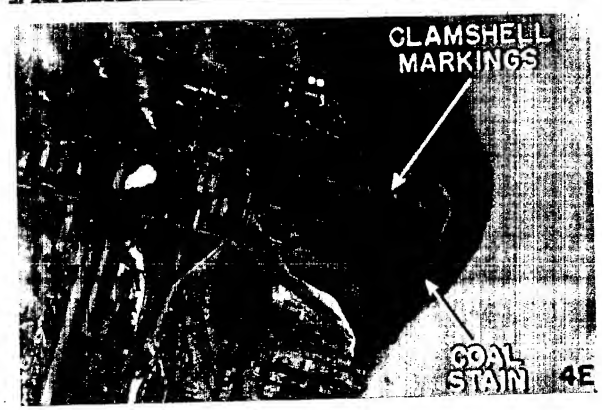
Loose coal piles are frequently levelled on top. Reserve coal supplies may be very neatly shaped and thus it is often possible to tell by the form and markings which part of the stock is being used and which is in reserve. Coal which has been levelled and left unused for some time will show erosion gullies, and these will indicate coal supplies in excess of current demands.

Coal has a shining surface which reflects light so that coal piles may photograph nearly any shade of gray depending on the amount and direction of light, and the character of the coal. Here are two types of domestic coal in hopper cars.


4C

This vertical view, below, shows how different qualities of coal may appear strikingly unlike in aerial photographs.


4D



4E

Coal storage near water can frequently be identified by a dark stain or scum on the water. This photograph also shows marks left by clam-shell buckets and other handling equipment.

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B. GAS

Two gases are referred to in connection with coke ovens, and care must be taken not to confuse them. They are: (1) *Fuel gas*, which is forced into the oven flues to heat and carbonize the coal, and (2) *By-product gas*, which is formed as a result of the carbonizing of the coal, and is sucked out of the coking chambers.

Modern coke ovens which are operated in connection with blast furnaces will use a large percentage of blast furnace gas as a fuel. However, coke ovens can also use gas produced in their own coking process, or a mixture of this and other gases. When by-product coke oven gas is used as fuel, it will first pass through equipment for removing various components of the gas, such as benzol, toluol, ammonia, and tar, before it enters the oven heating chambers. This is discussed under "Coke Oven By-products." In the beehive process the gases are consumed during coking so that none are available for use as fuel.

Only moderate-sized coke oven gas storage will be found in a steel plant because the gas is used almost as quickly as it is produced: on the other hand, when coke ovens are used for public utility or chemical plants, the gas holder will be incomparably larger.

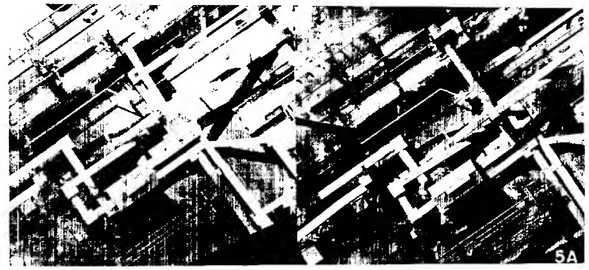
PROCESSES USED

Coke is made by heating coal in the absence of air, which results in the expulsion of almost all the volatile material and leaves nearly pure carbon. This is called "destructive distillation". There are two methods for making coke: (1) the *beehive* process, and (2) the *by-product* process. The beehive oven supplied the steel industry with coke for many decades, but it is very primitive and wasteful, and since the turn of the century it has been largely discarded for the by-product oven.

A. BY-PRODUCT PROCESS

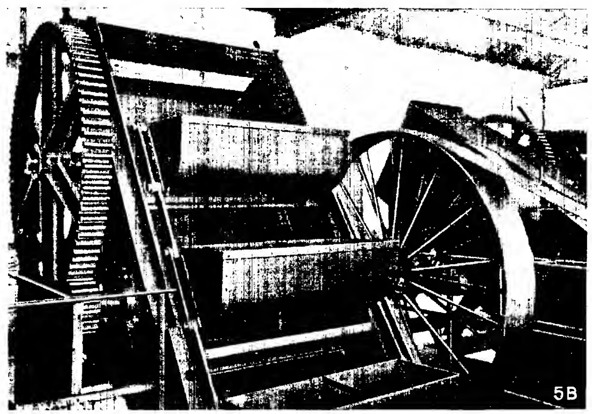
By-product ovens are frequently served by a criss-cross system of enclosed inclined conveyors, which can be easily distinguished from the rest of the plant area. A good example of this is seen in the full-page view on the next page.

These conveyors also appear criss-cross in a vertical view as in the stereogram below.



5A

Such systems act completely automatically, and make possible the handling of hundreds of tons of coal and coke per day. The typical conveyor consists of small buckets mounted on an endless belt....................

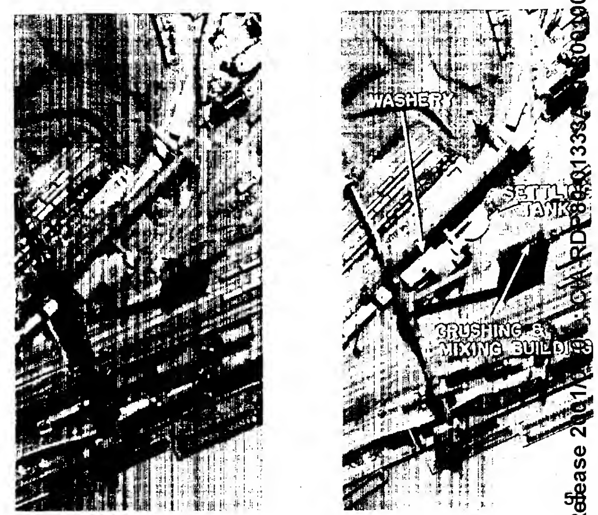


5B

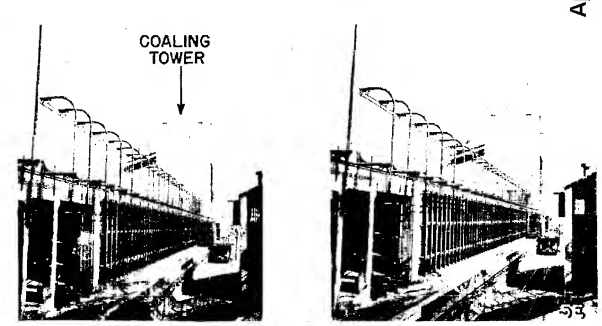
.........or sometimes just an endless belt by itself.

5C

The coal is transported from storage to the *washery*. where it is cleaned, or "washed", to free it of slate, unless it has previously been cleaned at the mine. This washing is done in settling tanks, where the coal is floated away from the heavier slate. Then it may be screened, crushed to uniform size, and blended with other coal in the *crushing* and *mixing buildings*. Its course can be traced by the slant of the conveyors, which enter the buildings at the top, and leave from the bottom.



The clean blended coal finally completes its long up and down zigzag journey through the maze of conveyor belts, and ends in the *coaling tower*.



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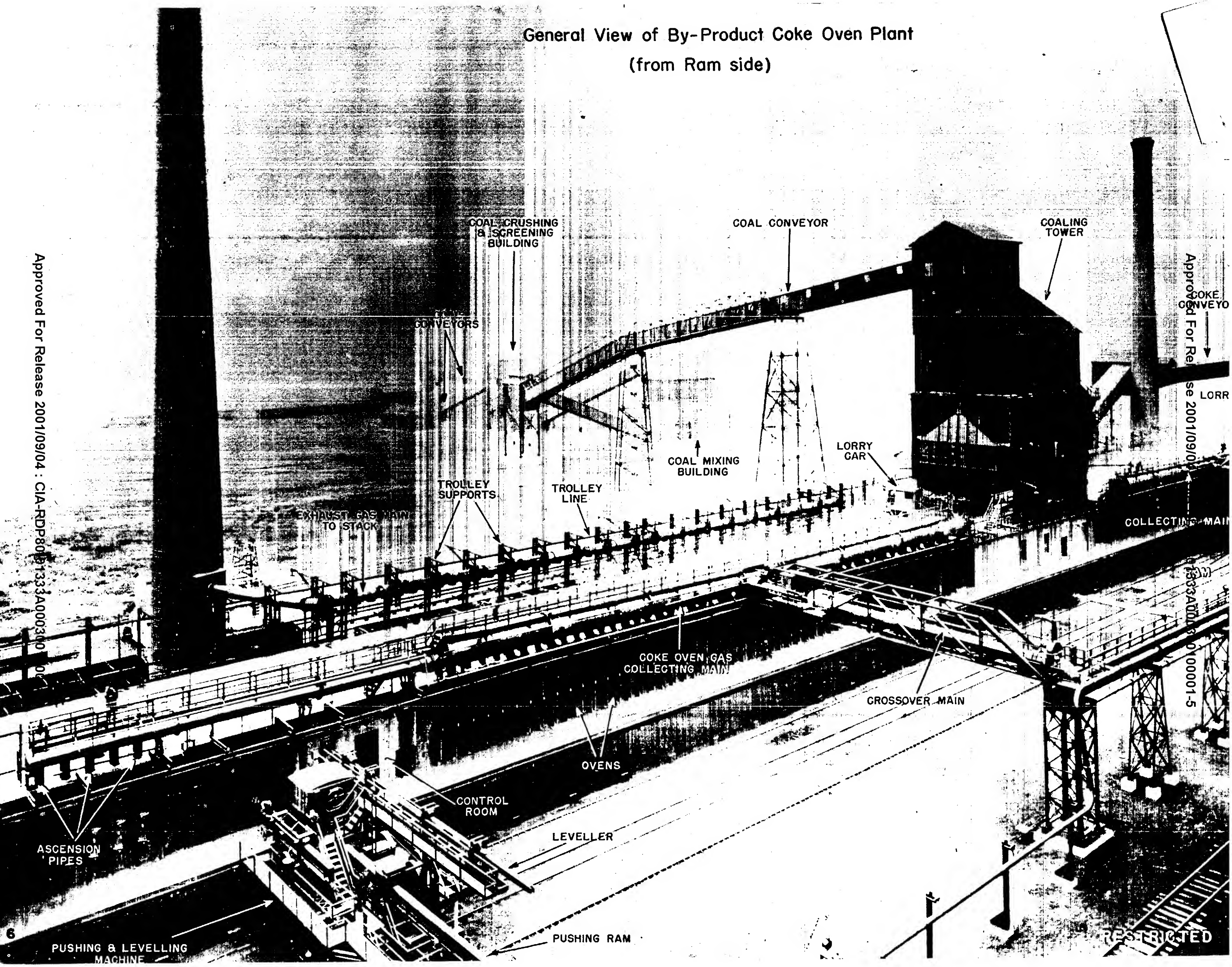
General View of By-Product Coke Oven Plant

(from Ram side)



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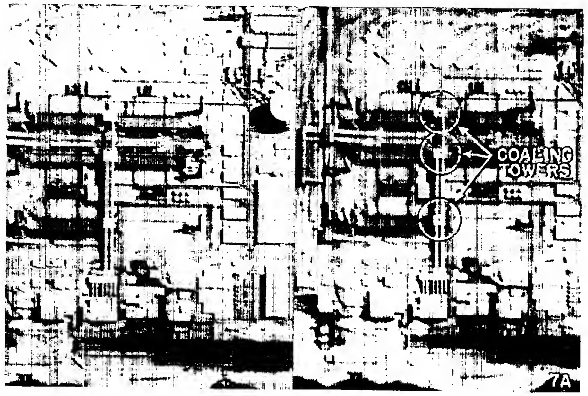
The stereogram below shows coaling towers in vertical view:

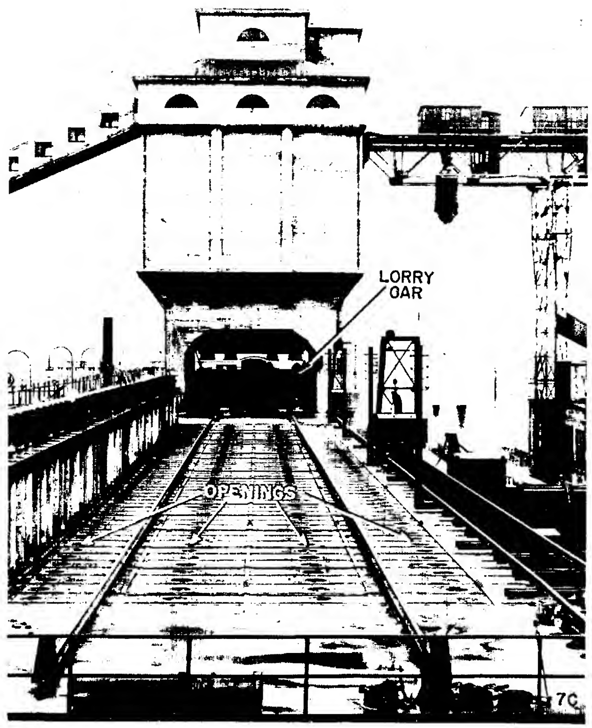


7A

The design and shape of the coaling tower depend largely on the whim of the designer. However, the design of the tower does not greatly affect the appearance in vertical view. The tower can always be recognized by its great height rising from the long row of ovens, and by the conveyor running to it. Coaling towers are important to regular and efficient operation because such large volumes of coal are handled. If one were destroyed, the coal would have to be fed into ovens manually, and production would be reduced tremendously if not entirely stopped.

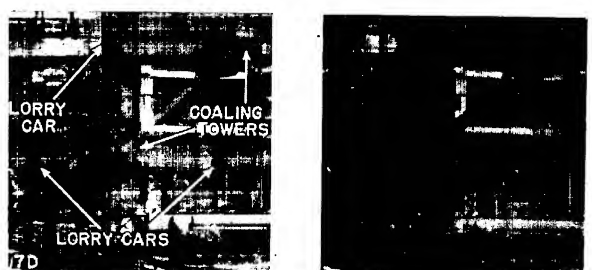
From the coaling tower the coal is dropped through hoppers to a *lorry* or *charging car,* which consists of from one to four hopper-shaped vessels built on a railroad truck. The lorry car in the photograph below has just been loaded from the coaling tower above it.

7B



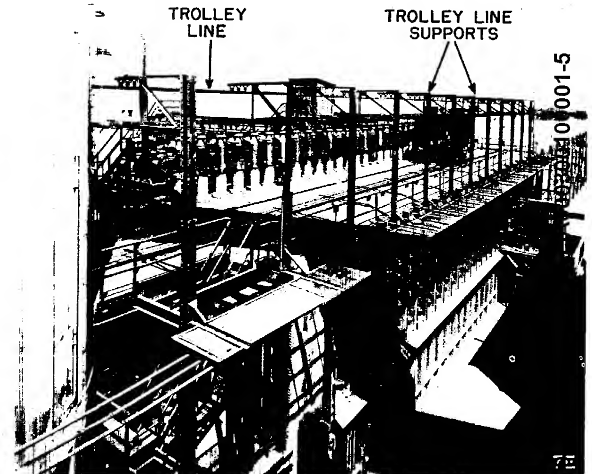
7C

The following stereogram shows how lorry cars appear from the air.



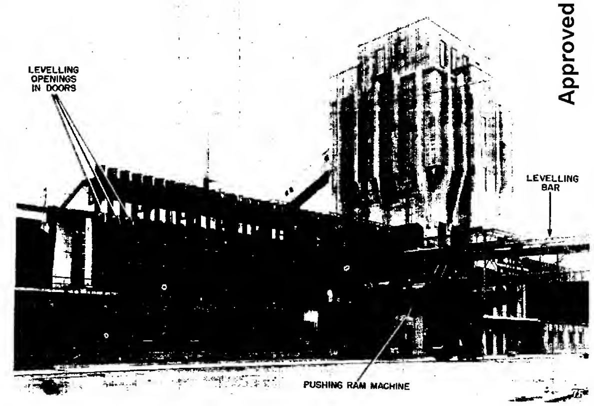
7D

In order to charge an oven, the car rides on rails over the top of the battery until it reaches the unit to be charged, and there the coal is dumped into the oven openings. Each oven has from one to four openings in the top. The lorry car is generally powered by an electric trolley line which is strung along one side of the oven battery.



7E

When the coal is charged into the top of the oven it forms into uneven piles below each charge hole. The coal must then be levelled, which is done by the *levelling-bar* on the pushing ram machine, which will be described further on.



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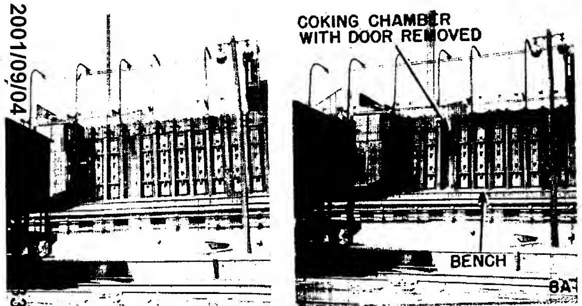
COKE

This levelling-bar is mechanically operated, and enters the oven through a small opening in the oven door on the pusher side, which can be seen on the last photo. The levelling-bar rakes through the oven and levels the coal. Some ovens are equipped with a separate levelling machine, and in this case only one bar will be seen projecting from the pushing machine. After the coal has been dumped into the oven and levelled, the oven is said to be charged and ready for the production of coke.

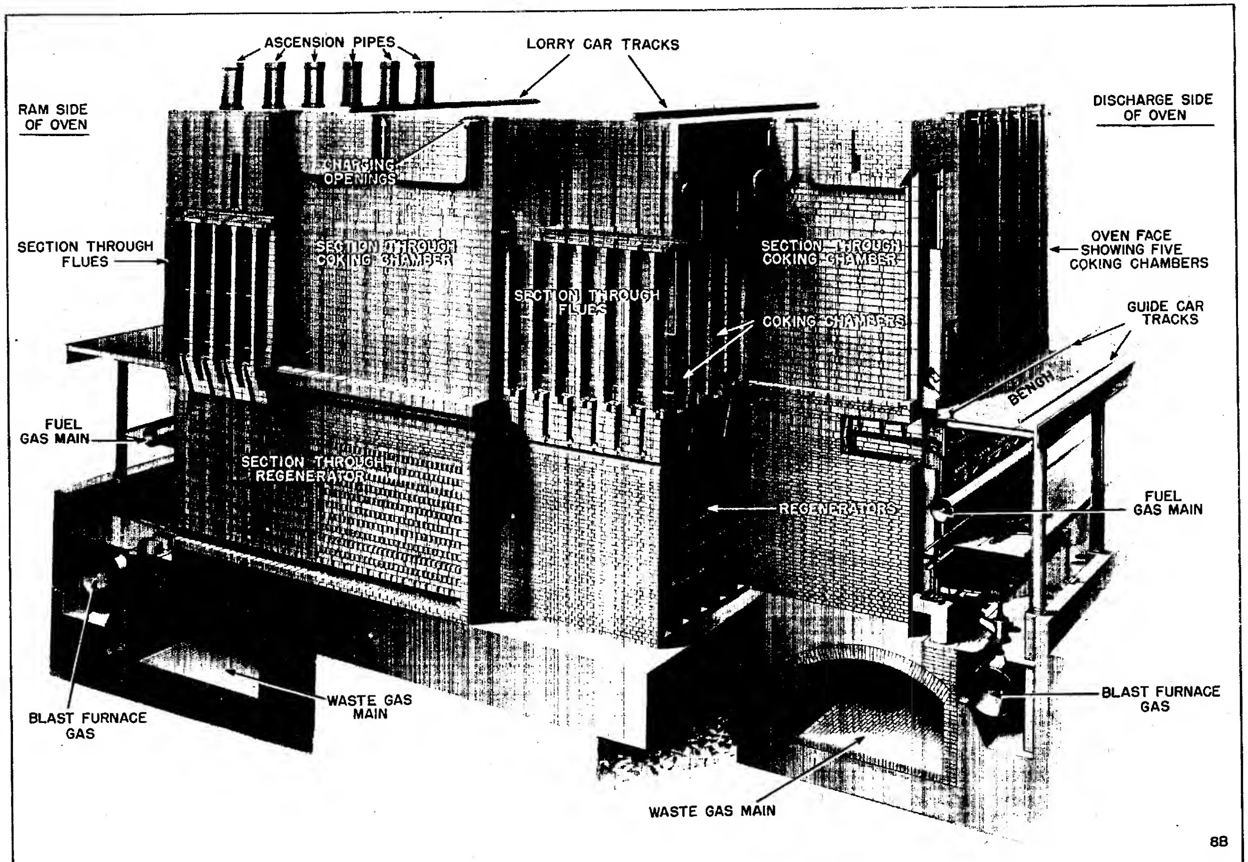
A distinguishing feature of a by-product oven is that the coal is carbonized by heat from ignited gases which do not come in contact with the coal. There are several varieties of by-product ovens; one widely used is the Becker (Koppers) type, which has been selected for description here. It is representative of standard by-product ovens.



Each single oven is tall and narrow. This stereogram shows a series of ovens with the door removed from one of them. It also shows how ovens are built side by side in a long row, there being anywhere from 25 to 60 oven compartments in a unit. The combined unit is called a battery. Each oven in a battery is charged and discharged separately.

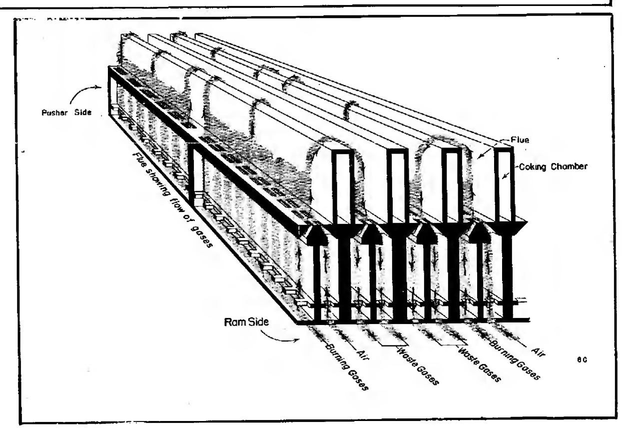
The ovens are constructed almost entirely of brick, and in their walls, floors, and roofs are built flame flues, outgoing flues, and regenerators. The part of the oven where the coal is coked is called the *coking chamber*.

Fig. 8B **is a cutaway view of a small portion of a battery of coke ovens and gives some impression of its complexity.**



First, the gas is carried to the ovens in two large iron mains which travel along the entire length of the battery under the benches on both sides. This is shown above. The incoming or burning gas is then pre-heated in the regenerators, and ascends into the flame flues where it is mixed with air and ignites. These flues line the entire length of each wall. Combustion takes place simultaneously in all the vertical heating flues of one wall. The heat of the burning gas is transmitted to the coal in the coking chamber, which is thus carbonized, that is, formed into coke.

The flow of gas during the heating of the coking chamber is illustrated and described in the diagram to the right.



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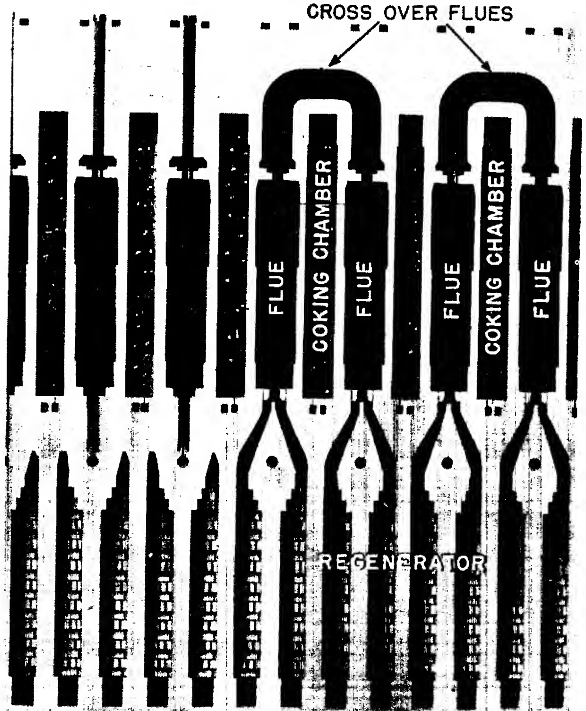
The ignited gases pass over the top of the coking chamber, through cross-over flues down into the heating flues of the opposite wall. In some ovens, the gas goes up one flue and down another on the same side of the ovens. Crossover flues are not constructed in this type of oven. After burning, the resulting waste gases are drawn down through the regenerators and are carried away in two large brick-lined mains located under the ovens, which conduct the gas to the tall stack associated with the battery. Any break in these gas mains could cause damaging explosions.

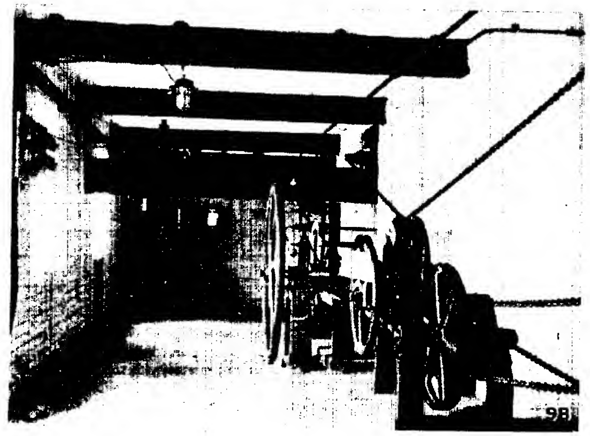
Below is a more detailed drawing of the flues:



9A

At regular intervals the direction of gas flow is reversed, so that the incoming gas and air are always heated upon entering, and are cooled before leaving. In order to prevent combustible gas from passing from the regenerators up the stack flue and exploding while reversing, the reversing machine is set to allow a short time between closing the gas cocks on one side of the battery and opening them on the other.

The reversing is carried out by a central reversing machine as shown here.



9B

This machine is in the *control room* or the *reversing room*, which may be located at the end of the battery in any one of the following places: (1) underneath the coaling tower, (2) between the coaling tower and the oven immediately adjoining, (3) between two batteries.

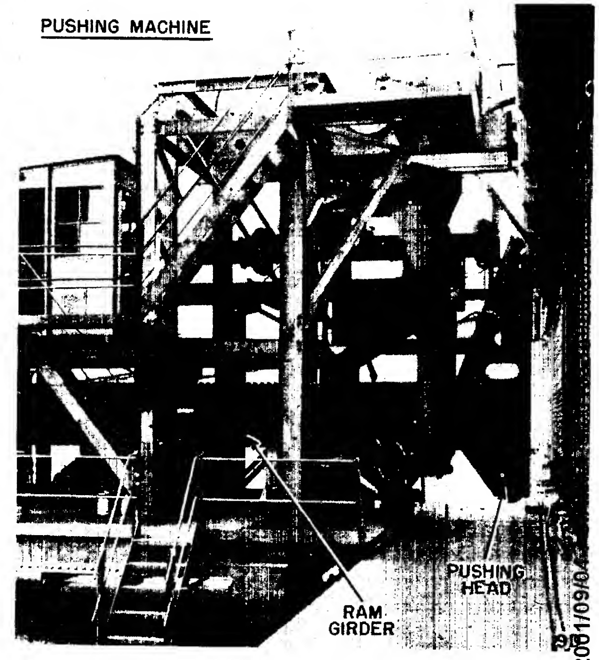
The coking process requires from 15 to 20 hours depending, among other factors, upon the kind of coal, the type or width of oven. When the coking is completed, the *pushing machine* or *pusher*, which travels on rails, removes the oven door.

9C

Equipment for discharging the coke consists of a mechanically moved girder fitted with a pushing head, which transfers the pressure exerted by the girder to the entire face of the coke cake.

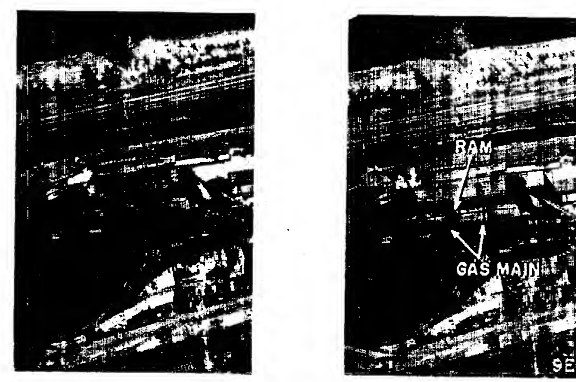
This pusher is called a *ram* and the side of the oven from which the coke is pushed is called the *ram side*.

PUSHING MACHINE



9D

A modern pushing machine is a combination of thre machines, which (1) levels the coke; (2) removes a replaces the door; (3) rams the coke. This is h pushing rams look from the air: Gas mains should not mistaken for rams.



9E

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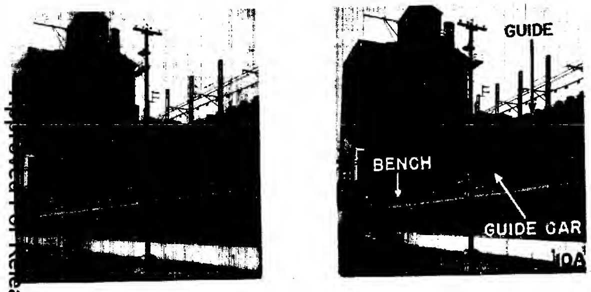
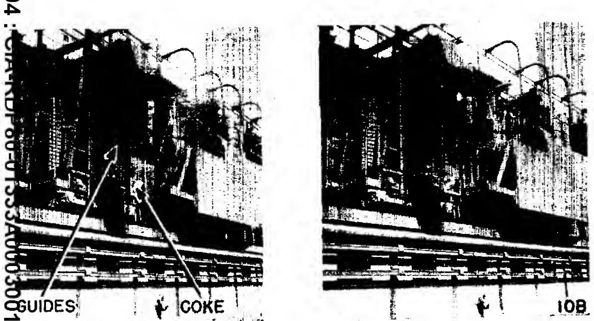
COKE

When the coke is ready for discharging from the oven, and the pushing ram is moved in place on the ram side, the door of the oven is removed. On the opposite, or discharge side of the oven, the *guide car* moves into place.



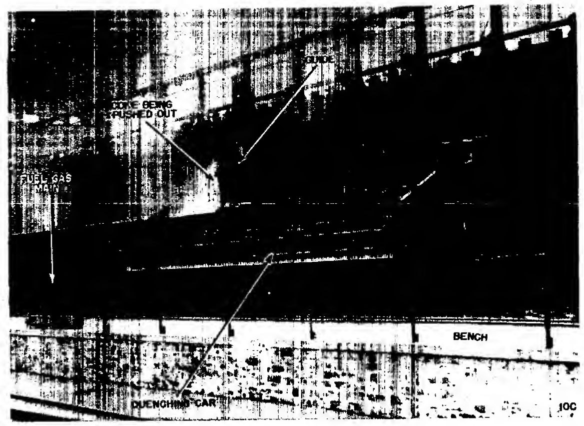
This car travels on the *bench*, which is a platform in front of the oven at the level of the oven floor. The guide car has a mechanism which removes the oven door.



This close-up view shows the *guides*, which resemble two vertical rows of iron slats. The coke is just beginning to emerge from between the guides. In the view at the top of the next column, a car, called the *quenching car*, is receiving the discharged coke.

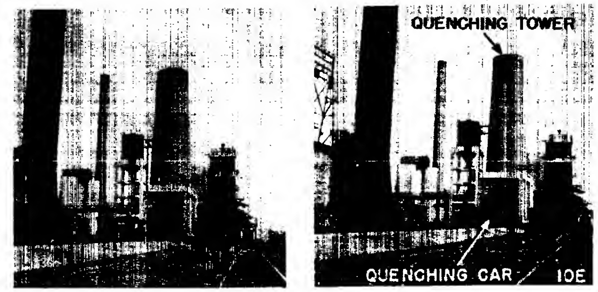
The coking process is completed in from 15 to 17 hours, depending on the type of oven and the quality of coal. Each oven chamber is discharged separately, and the timing of these operations is staggered. In a battery of 60 ovens one of the chambers will be discharged approximately every 15 minutes. Thus the operation of a coking plant is in effect continuous.

The charging is so spaced that every sixth or seventh oven is at about the same state of carbonization and will be ready for discharge at nearly the same time.

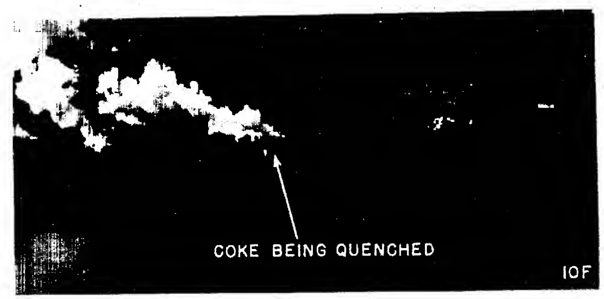


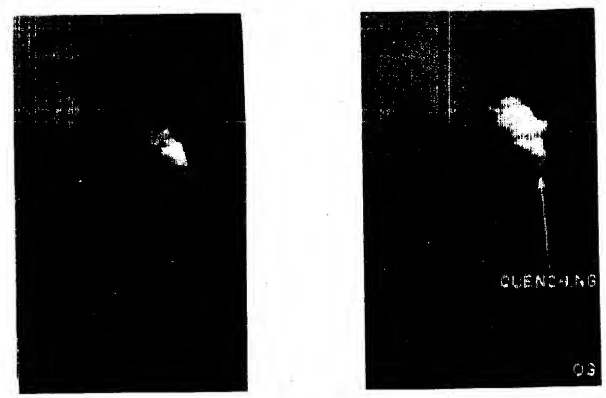
One side is slanting to allow easy removal of coke when it is dumped.

The white-hot coke must be cooled immediately or it will be consumed by the oxygen in the air. In order to accomplish this cooling, the quenching car is run into the *quenching tower*, where water is sprayed on the coke.



This creates a heavy cloud of steam, and when the tower is photographed while quenching, the steam will indicate its location.





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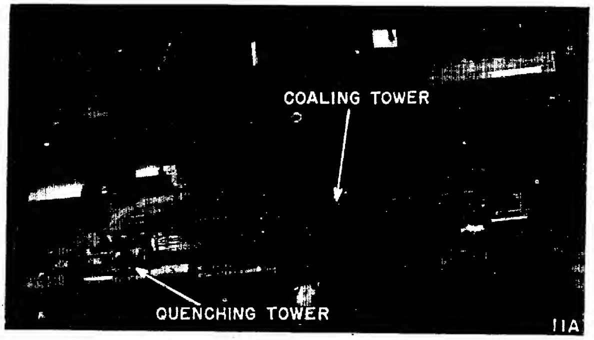
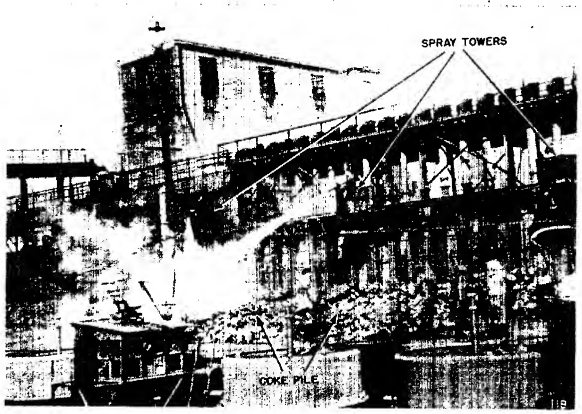
The tower is generally at the end of the battery of ovens, and can easily be distinguished from the coaling tower by its open top and absence of conveyors, as shown in photo.



11A

Characteristic of the older quenching methods used by the Japanese for some operations, is this example at Anshan where men are seen spraying hot coke by hand: This type of quenching will not be found at the new ovens built within the last 10 years.

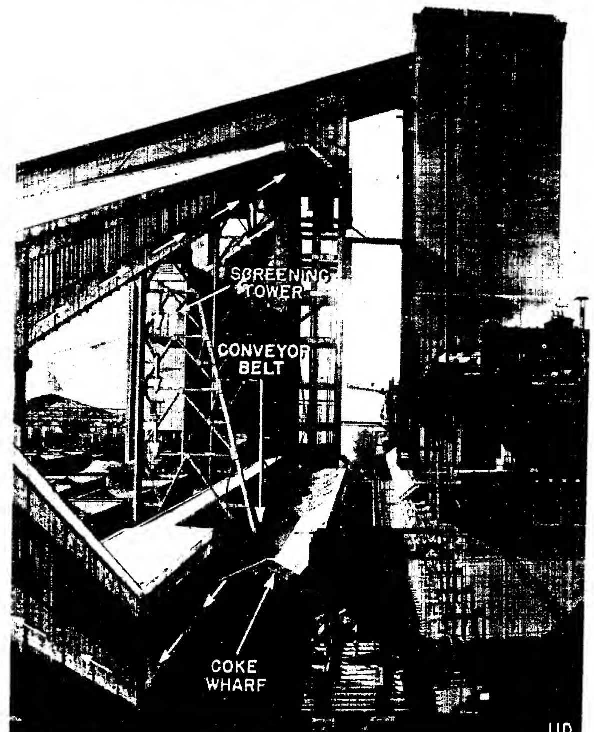


11B

After the coke is quenched, it is carried in the quenching car to the *coke wharf*, which is an inclined area alongside the quenching car tracks. The coke is dumped here and spread out in a comparatively thin layer to facilitate cooling and quenching of any local hot spots.

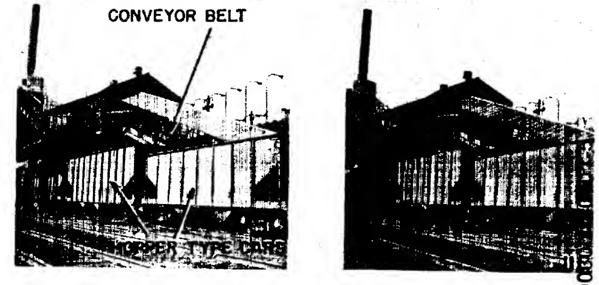
11C

The coke slides onto a conveyor belt which transfers it to the *screening tower*.

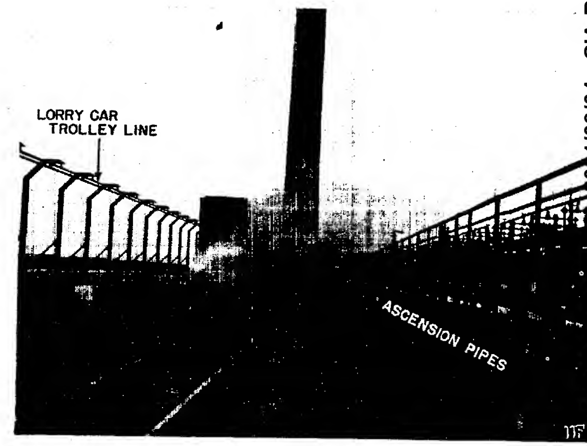


11D

Arrows show the direction of coke travelling to the tower. Loaded cars are seen in the background. Below coke is being loaded into hopper-type cars.



During the carbonization of the coal in the ovens gas and tar are produced as by-products. The gaseous elements are called *coke-oven gases*. They are drawn off by pipes which project vertically from the top of the oven.



11F

These pipes are known as *ascension* or *stand pipes*. They are short stubby pipes from 2 to 10 feet long, and are arranged in a row, usually along the ram side of the battery. They are commonly made of steel with a brick or plastic refractory lining. Each ascension pipe represents one oven, so that on sufficiently clear and large-scale photography the exact number of ovens in a battery can be determined. This fact can be used to estimate the approximate capacity of a coking plant as described at the end of this section.

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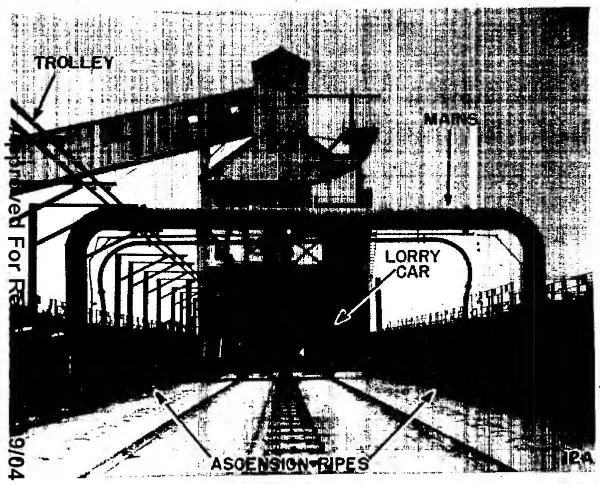
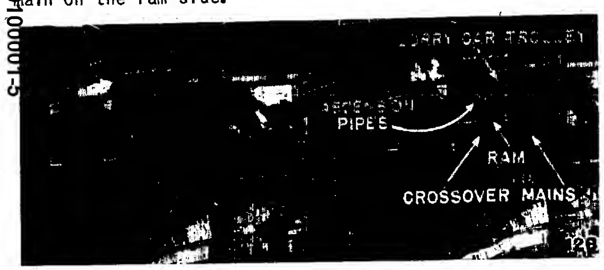
In a few instances coke ovens will have a double row of ascension pipes, that is, one row on each side of the battery. Two collecting mains are necessary and they will be connected by a large main crossing above the oven. This arrangement is shown below.



12A

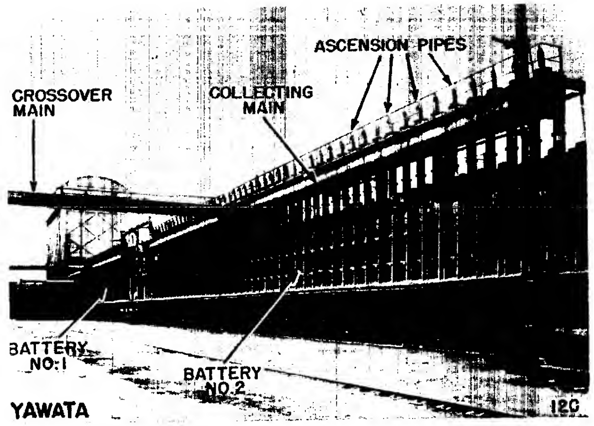
A removable cap is let into each ascension pipe, to provide for cleaning, or as an outlet for gases if required during opening of the oven. These vents may also serve as an emergency gas escape. They can be readily opened by a man riding on the lorry car. Thick smoke will be seen issuing from open vents of the ovens where carbonization is not too far along.

In vertical view, ascension pipes may be confused with supports for the lorry car trolley wire; but it will be noticed that the ascension pipes are very close together and are connected to the large collecting main on the ram side.



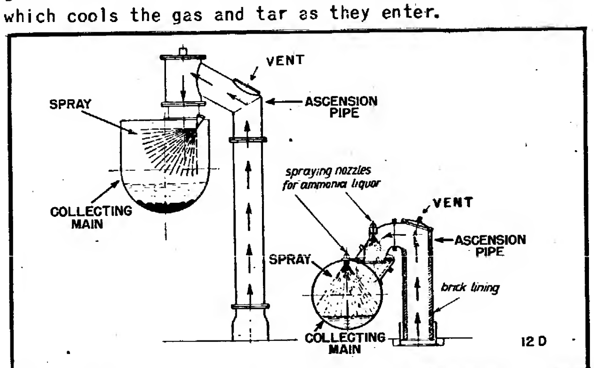
12B

The *collecting main* or *hydraulic main* is the gas receiver for all the ascension pipes in a battery and carries away the accumulated coke-oven gas to the by-product plant. Collecting pipes are necessarily large to accomodate the great volumes of gas produced in the ovens. Mains as large as $5\frac{1}{2}$ feet have been used, although 2 to 3 foot diameters are more common.



12C

The collecting main extends the entire length of the battery. In the above photo there are two batteries of ovens, each having its own main. Collecting mains are usually trough-shaped or circular in cross-section, and, in combination with the ascension pipes, serve to cool the distilled gases as well as transporting them. At the point where each ascension pipe enters the collecting main there is a valve or seal to prevent backflow of gases. An ammonia spray is set into the top of the main, which cools the gas and tar as they enter.

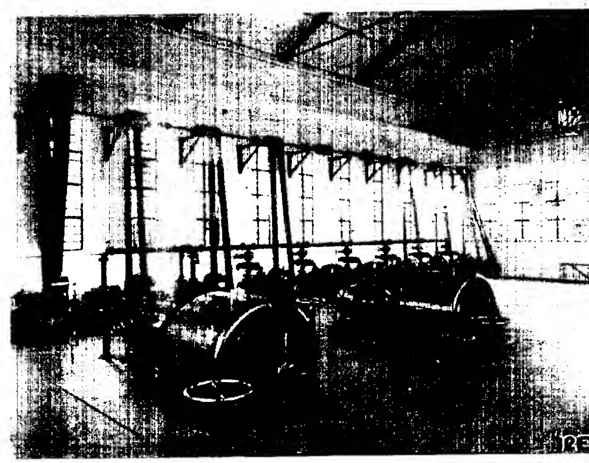


12 D

This results in the liquefaction of the heavier fractions. The ammonia also acts as a flushing agent, and keeps the main clean by carrying away the condensed tars. These large quantities of gases and liquids in the collecting main become highly explosive if air enters.

The third function of the collecting main is to stabilize the pressure of the gases issuing from the ascension pipes.

Coke-oven gases must travel a considerable distance from the coking chamber through the collecting main, other mains, coolers, extractors, washers, etc. Power required to propel the gas is furnished by a machine called an *exhauster*. It is really a vacuum-compressor.


12E

The exhauster creates suction in the collecting main, so that the gases are under suction until they pass through the exhauster, after which they are under pressure.

The proper adjustment of suction is of critical importance in the operation of the coke ovens. If there is too little suction, the gas pressure builds up in the oven chambers and the gas escapes into the air through leaks which develop in the oven. Too high suction is equally detrimental; the air is drawn into the coking chamber through any cracks present, raising the temperature and causing the combustion and decomposition of volumes of gas. Should the temperature rise to the fluxing point of brick, the structure of the oven would be destroyed. Other bad effects are created by improper suction, but those mentioned above are significant because of the explosive possibilities created in the ovens. The exhauster thus requires extremely delicate and accurate control.

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Two types of exhausters can be used: (1) *turbine* and (2) *piston*. The turbine exhauster is most commonly employed. It consists of a turbine wheel, equipped with many cup-shaped blades, which revolves at great speed, sucking gas from the incoming main and forcing it onwards. These turbine exhausters are sturdily built and will run efficiently for ten years or longer.

A spare exhauster is usually provided to cope with emergencies, which is why two appear in the photo above. This indicates the importance of this equipment; the exhauster is elaborate and costly and difficult to replace in wartime.

Gas exhausters are generally housed in a building together with the various pumps which serve for circulating tar, oil and other liquids at the by-product plant. This is called the by-product building, and is described in Section V. The exhauster room forms, to a certain extent, the heart of the coke oven plant and, therefore, of the entire steel plant.

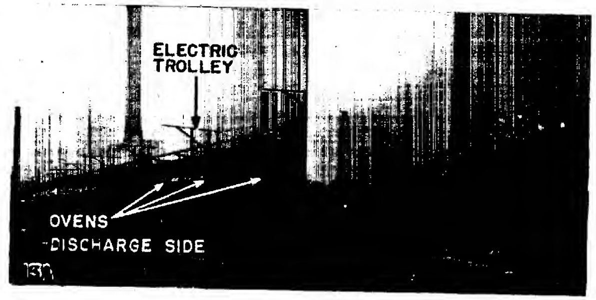
A distinctive feature of the by-product process is the saving of the gases produced by coking, and removal from them of tar, ammonia, benzol, toluol, and other fractions. The remaining gas may be used as a fuel, or as a chemical raw material. This is made possible by the basic principle of heating the coal without direct contact with the fuel gas, so that no combustion of by-product gas takes place. The invention of the by-product process has to a large extent made possible the development of the steel industry to its present size, because the by-product oven is larger and more efficient, and produces more coke in a shorter time than the old beehive method. It is also responsible for the development of new and valuable industries involving the coke oven by-products.

B. BEEHIVE PROCESS

The beehive oven, while producing excellent coke, is wasteful and uneconomical compared to the by-product oven. A great number of them is required to replace one by-product battery.

In the beehive process coal is burned in ovens until the volatile products are almost entirely eliminated. The process takes its name from the shape of the ovens. Originally each oven was built as an individual unit, so that there were a number of small separate structures.

Subsequently, it was found to be more economical to construct the units in rows of connected ovens forming a battery.

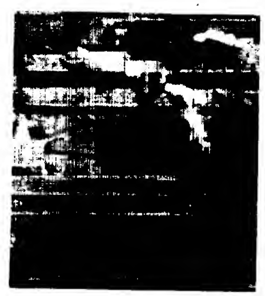


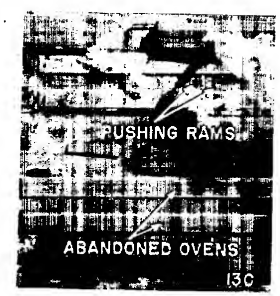
13A

A battery of beehive ovens is a long narrow brick structure with small dome-roofed cavities at regular intervals. The general appearance in aerial view is similar to a by-product battery, but less complicated. Here are a few batteries.

13B

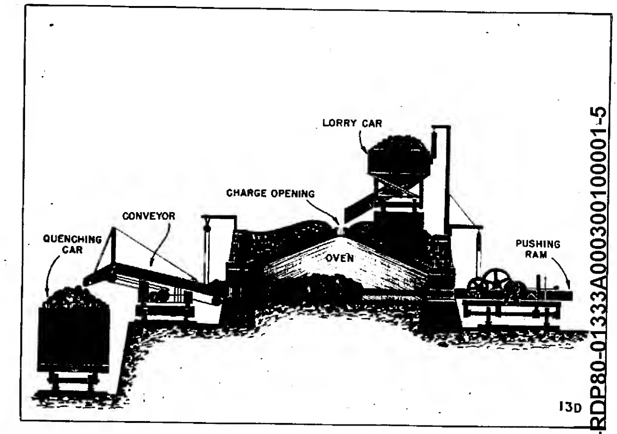
Two batteries have been abandoned. The absence of gas mains and an accompanying by-product plant will distinguish beehive ovens.





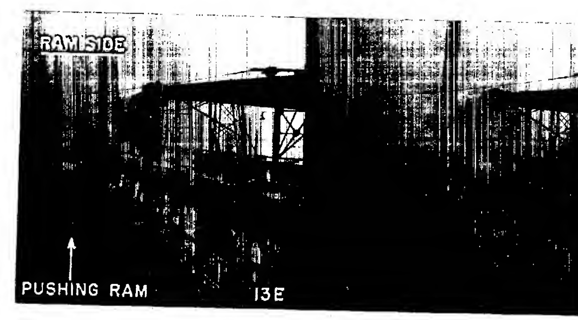
13C

The cross-section shows a modernized beehive oven that was adapted from the by-product oven. It has such improvements as the lorry car, pushing ram, and quenching car.



13D

The operation is simple: Coal is charged into the oven from the lorry car which travels over the top of the battery. The coal is then carbonized through heat formed by the combustion of part of the charge. The coke thus produced is then pushed out of the oven by a ram.



13E

The coke falls onto a moving belt outside the furnace and is carried into a car to be taken to the quenching tower. Old beehives, such as may be found in China are likely to be largely manually operated; a hand pusher may be used instead of the pushing ram.

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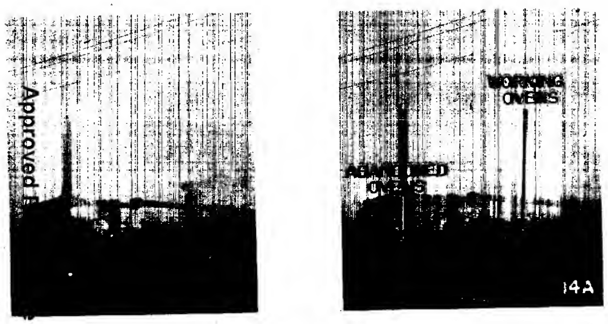
The gas which is driven off burns at the charging holes in the top of each oven and creates a characteristic murky haze around working beehive ovens. None of the valuable by-products or essential fuel gases are collected and, therefore, the beehive process is very uneconomical.



NOMENCLATURE OF COKE OVENS

Considerable confusion has been noticed among various agencies reporting from aerial photographs as to the number of coke oven batteries present. Although usually it is quite simple to recognize the limiting ends of each battery, complications do arise when this is not easy. It may become particularly difficult to determine the number of ovens when the original battery is extended by the addition of one or more batteries.

There seems to be no purpose served by reporting coke ovens in terms of batteries. The information desired usually is:

(1) The number of ovens.

(2) The productive capacity of the ovens in tons of coke per day.

The following nomenclature and system of reporting is suggested, therefore:

(1) Any connected series of ovens, whether consisting of one or more batteries be called a coke oven "installation".

(2) An "oven" will retain its customary designation, being described as one coking chamber with one flue on either side.

(3) Report coke ovens, as follows:

(a) Number of installations.

(b) Number of ovens in each installation.

By reporting coke ovens in this manner, there should be established a common ground for understanding, thereby eliminating the dangerous confusion which now exists.

PRODUCTIVE CAPACITY OF COKE OVENS

There are only a few manufacturers of coke ovens, and they supply the world. However, the sizes and dimensions of coke ovens vary greatly, so that only average dimensions can be given. Important coke oven data follows:

(1) Width of single oven is 3.6 feet from center to center.

(2) Width of retort is 17 inches.

(3) Height from ground to top of oven is 22 feet.

(4) Width of battery: old type--37 feet, new type--43 feet.

(5) Coke oven battery may have between 25 and 60 ovens.

(6) Control room of coke oven battery lies at one end of battery or between two batteries.

(7) Seven-tenths of a ton of coke is produced for every ton of coal carbonized in the oven.

(8) Average productive capacity of one oven is 15 tons coke per day.

The daily productive capacity of a coke oven installation can be approximately estimated from aerial photographs. The following information is needed:

A. Width of a single oven. (No. 1)

B. Amount of coke produced per oven per day. (No. 8)

C. Total length of oven installation. This figure is a variable and can be obtained from aerial photographs in three different ways:

(1) Count the approximate number of ascension pipes. Excellent large scale photography is necessary.

(2) Measure the extent of the ascension pipes on top of oven battery as in (A) of following stereogram. Dividing this figure by 3.6 will give the approximate number of ovens.

(3) Measure length of coke oven installation and subtract the portion occupied by the coaling tower and the buttresses at each end, as in (B) of the above stereogram. Dividing the resulting length by 3.6 will give the approximate number of ovens.

Having obtained the number of ovens, then it is only necessary to multiply that figure by 15 (tons of coke / day / oven) to get the approximate daily production for the entire installation.

It should be understood that because of occasional wide variation in the dimensions of ovens, quantity of coal charged, and time required for carbonizing charge, the figure of 15 tons coke production per day represents a very rough estimate. Production capacities calculated with this figure should be used with discretion.

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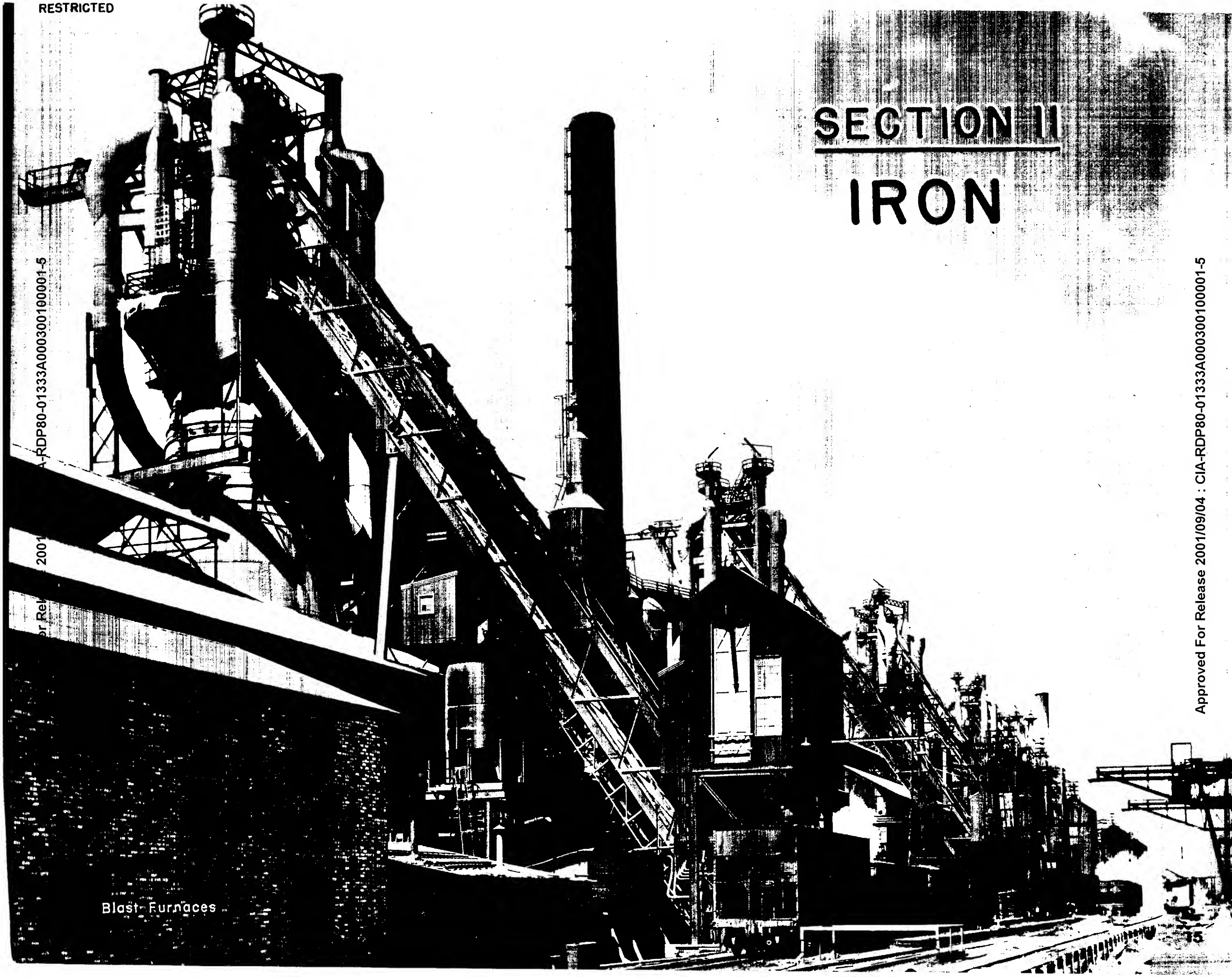
SECTION II
IRON



Blast Furnaces

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IMPORTANCE OF PRODUCT

A sufficiency of iron and steel is a basic prerequisite for any industrialized nation and particularly for one engaged in modern warfare. Pig iron is essential for the manufacture of iron castings, steel and steel products. One exception to this statement may be noted: The Japanese steel industry produces a small quantity of high-carbon steel directly from iron ore and iron sand by the use of an electric process. This process will be touched upon lightly in the following section on Steel. It has not appreciably affected the importance of pig iron as a central product in the steel industry.

RAW MATERIALS

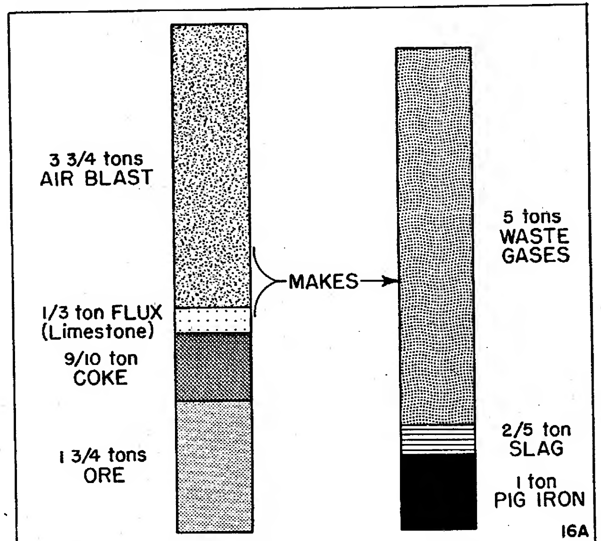
1. *Iron Ore*
2. *Coke*
3. *Limestone*
4. *Air*

These are the raw materials required to produce iron. They are used in titanic quantities. For instance, the operation of a large modern blast furnace which produces 1,000 tons of pig iron per day, will consume the following amounts of raw material every 24 hours:

Ore	- 1700 tons
Coke	- 900 "
Limestone	- 500 "
Hot Air Blast	- 9000 "

Seven to eight million gallons of *water* per day are also required in the smelting of iron, but should not be considered as a raw material because it is not mixed with the other ingredients. The water is circulated through water-jackets in the walls of the blast furnace, where it serves as a cooling agent. This cooling is indispensable; if the circulation of water were interrupted, the furnace would overheat and operation cease within a few minutes.

This graph shows the average quantities needed to produce one ton of pig iron:



16A

A considerable quantity of blast-furnace gas and slag are also formed along with this ton of iron. The gas is valuable as fuel, but the slag is comparatively worthless.

A. LIMESTONE

Limestone is used as a flux in smelting iron. It is not uncommon for limestone quarries to be located in close association with iron and steel plants. The quarry shown below supplies three blast furnaces.

16B

B. COKE

Because of its breakable structure, coke is generally brought to the furnace as directly as possible from the ovens, in order to subject it to a minimum of handling. Its use in smelting is described on Page 4.

C. ORE

Although Japan obtains some rich oxide ore from Paracele in the Philippines and possibly from Malaya, the Japanese have been obliged to augment their supply by exploitation of low-grade ores. Examples of such ores are limonite, which is an oxide ore of low iron content, and poor grade hematite and magnetite.

Iron sulfide, scientifically called "pyrites" but more universally known as "fool's gold", is also used. Pyrite does not contain sufficient iron content to be classed as an ore. In industry, this mineral may be mined for the extraction of the more valuable metals, or for the manufacture of the sulfuric acid. In these cases, the iron recovered is really a by-product, even though the tonnage may be appreciable. The interpreter should be on the lookout for these associated iron concentration mills when working with Far East photography. The Besshi copper mine in Japan is a good example of the concentration of iron as a by-product. Here the burned pyrite is hand picked after being crushed to size.

Ore must often receive preliminary treatment before it can be used in the blast furnace. This may be done at the plant, but with low grade ores it is usually more economical to treat them near the mine. The treatment consists of concentrating the iron content, thereby avoiding transportation of excess waste material.

COBBING METHOD: The iron ore is broken out of the surrounding minerals with hand hammers. This work may be done either under sheds or in the open, according to climatic conditions.

GRAVITATIONAL METHOD: The ore containing iron mineral is first crushed to a fine size. The separation of the iron mineral is possible because of the great difference in weight between the iron and other minerals. The crushing, screening, and concentration is usually carried out in typical mill-type buildings served by inclined conveyors much in the same manner as pictured and described for coke. A source of water should be apparent. Thickener tanks may be present where the wet process of concentration is used.

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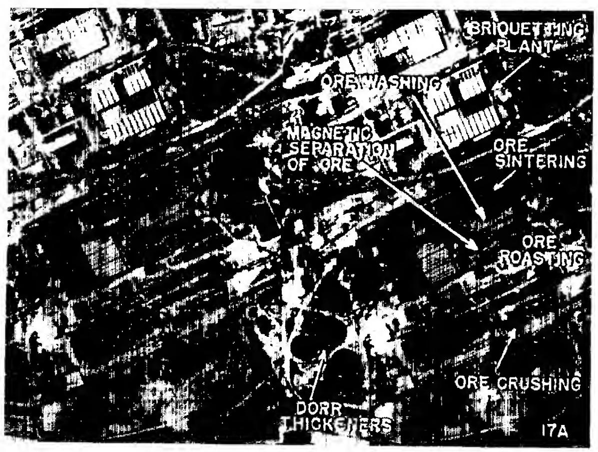
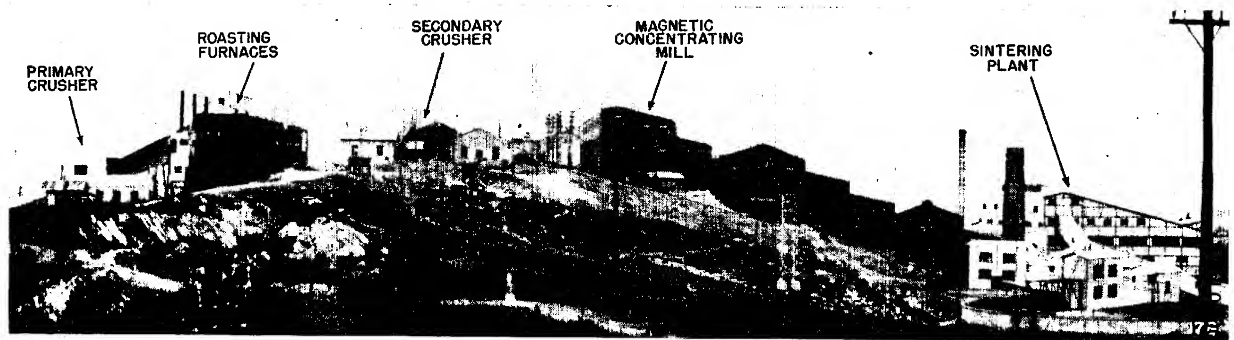
MAGNETIC METHOD: Rock containing magnetite, such as is concentrated at Mozan, is first crushed and then subjected to a magnetic field which separates the magnetic iron oxide from the minerals. Washing may accompany magnetic separation, or a dry magnetic separation may be used.

DRYING: Much of the ore now available to Japan is of the limonite type. It contains somewhat more than 30% of water, and concentration is gained by crushing the ore and roasting it in furnaces. This drives out the water.

At Anshan, Manchuria, low grade hematite is roasted magnetically to produce magnetite, then concentrated and either sintered or briquetted. Here is a vertical view of the Anshan ore concentration plant in which the interpreter will notice the resemblance between roasting kilns and coke ovens.



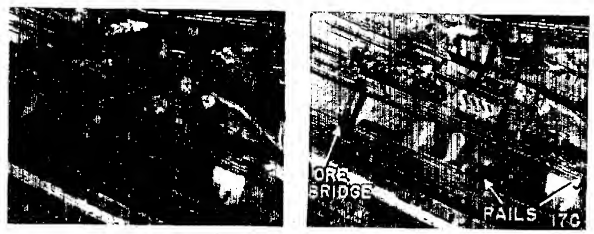
The concentration processes leave the iron ore finely divided and unsuitable for use in blast furnaces, as the fine particles would be blown out by the strong hot air blast. The concentrate is, therefore, sent to a sintering plant where it is heated until it is partially fused into a sort of clinker. It then can be shipped as an iron ore suitable for blast furnace use.



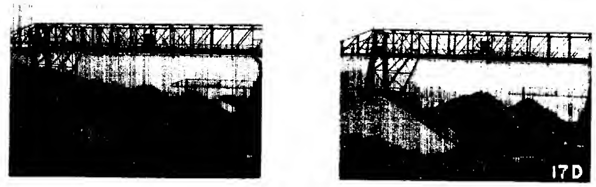
An early ground shot of the Anshan ore concentration plant shown in 17A.

D. STORAGE OF RAW MATERIALS

Storage areas of a blast furnace plant are necessarily very large except in cases where the plant is close to mines which produce a steady flow of raw materials. The storage piles shown below supply a small set-up of three furnaces:



The stored ore and limestone are handled by giant travelling ore-bridges which move on two rails, one on either side of the storage piles. The ore-bridges of the above plant are shown in this ground stereogram, taken at a later date:



The two white piles, one in the foreground and one in the background, consist of limestone; the others are ore. Three varieties of ore can be distinguished here by difference in tone.

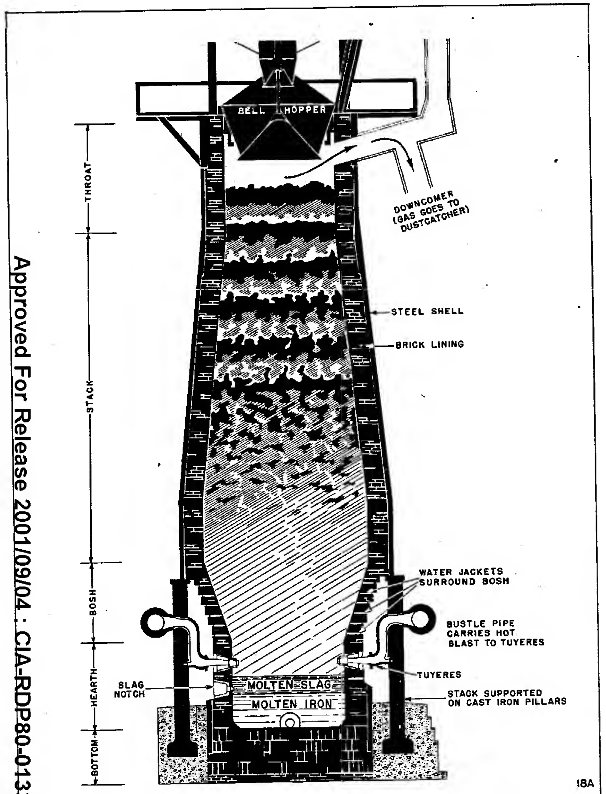
PROCESSES USED

A. THE BLAST FURNACE

The blast furnace is an indispensable installation in the iron and steel industry. It is the meeting-place of the raw materials from which iron is produced.

A modern blast furnace set-up includes, in addition to the furnaces themselves, a group of hot stoves for pre-heating the blast, gas cleaning devices, large storage areas and bins, charging cars and equipment, water pumps, ladles for taking away the slag and pig iron, casting machinery, blowers, and power houses. A battery of gas engines in which some of the blast furnace gas is converted into electricity is also frequently found in the blast furnace plant. All these adjacent structures can make it rather difficult for the interpreter to pick out the location of the furnace in vertical photography.

A blast furnace may be described simply as a cylindrical steel shell lined throughout with firebrick. It may be from 40 to above 100 feet in height. The lowest section is the *bottom* of the furnace, which is made up of a solid mass of firebrick. The thickness varies with the size of the furnace, from 5 to 6 feet in the case of smaller furnaces, and from 12 to 14 feet in the larger furnaces. These bricks must be laid very closely to prevent loss of metal. The high grade firebrick is underlaid by firebrick of a cheaper grade and this in turn by concrete in a deep and broad foundation, giving absolute stability.



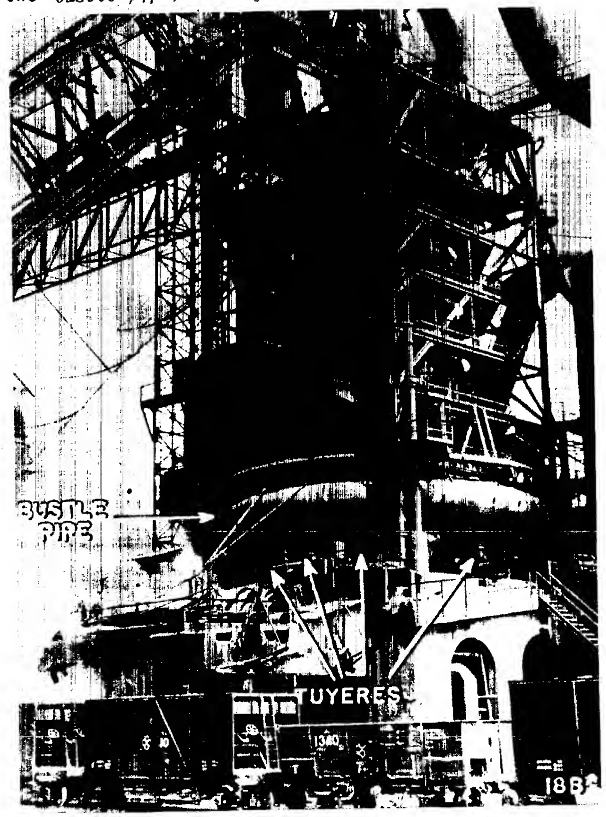
Diagramatically it can be divided into five parts, as indicated in this simplified artist's drawing, which is a cross-section through the center of the blast furnace.

Overlying the bottom is the *hearth* of the furnace, which is cylindrical in shape. It consists of a fire-brick lining, usually 27 to 32 inches in thickness, surrounded by a steel or iron jacket. The walls are cooled by water sprays or troughs, or by built-in water pipes. It is in the hearth that the molten iron and overlying slag collects.

Above the hearth is a funnel-shaped section called the *bosh*. It is usually made of brick-work 27 inches or more in thickness. Inserted in the brickwork are numerous wedge-shaped hollow bronze castings, or *water-jackets* through which water is circulated to cool the brickwork and preserve the furnace lines.

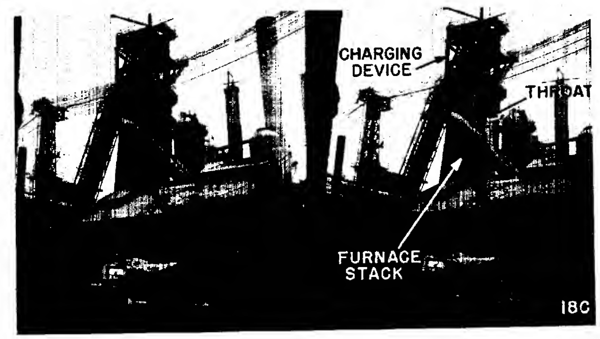
The next higher, and longest section of all is known as the *shaft* or *stack* of the furnace. It is roughly conical in shape, being larger in diameter at the bottom than at the top. The lining thickness varies from 36 to 48 inches. The stack is constructed of firebrick surrounded by a steel shell, the latter being supported by cast iron pillars resting on the furnace foundation. This relieves the lower portion of the furnace of the weight of the stack. The top section is the *throat*, where the blast furnace gases accumulate and are drawn off, and where the raw materials are fed into the furnace.

Where the hearth joins the bosh a series of 10 to 15 pipes enter the furnace at points arranged symmetrically around the circumference. These are called the *tuyeres*. It is through these pipes that the air blast enters the furnace. Surrounding the bosh about midway up is the *bustle pipe*, a large annular pipe from which the



tuyeres lead. This pipe, which is lined with 9 to 12 inches of firebrick, conducts the hot blast to the tuyeres. The furnace shown is in the Showa works in Anshan, Manchuria.

The throat of the furnace is topped by an ingenious device known as the *bell and hopper* and by a complicated mass of steel framework which supports the charging apparatus. The bell and hopper is a cone-shaped affair through which the raw materials are charged into the furnace, and which prevents the escape of combustible gases during charging operations. The upper half of the stack, the throat, and the charging device are shown in this stereogram:



A close-up of the bell and hopper device is shown below:

CHARGING THE BLAST FURNACE: The charging of a blast furnace is a lengthy procedure, and the raw materials undergo considerable hauling and dumping before they reach the throat of the furnace. Ore and limestone

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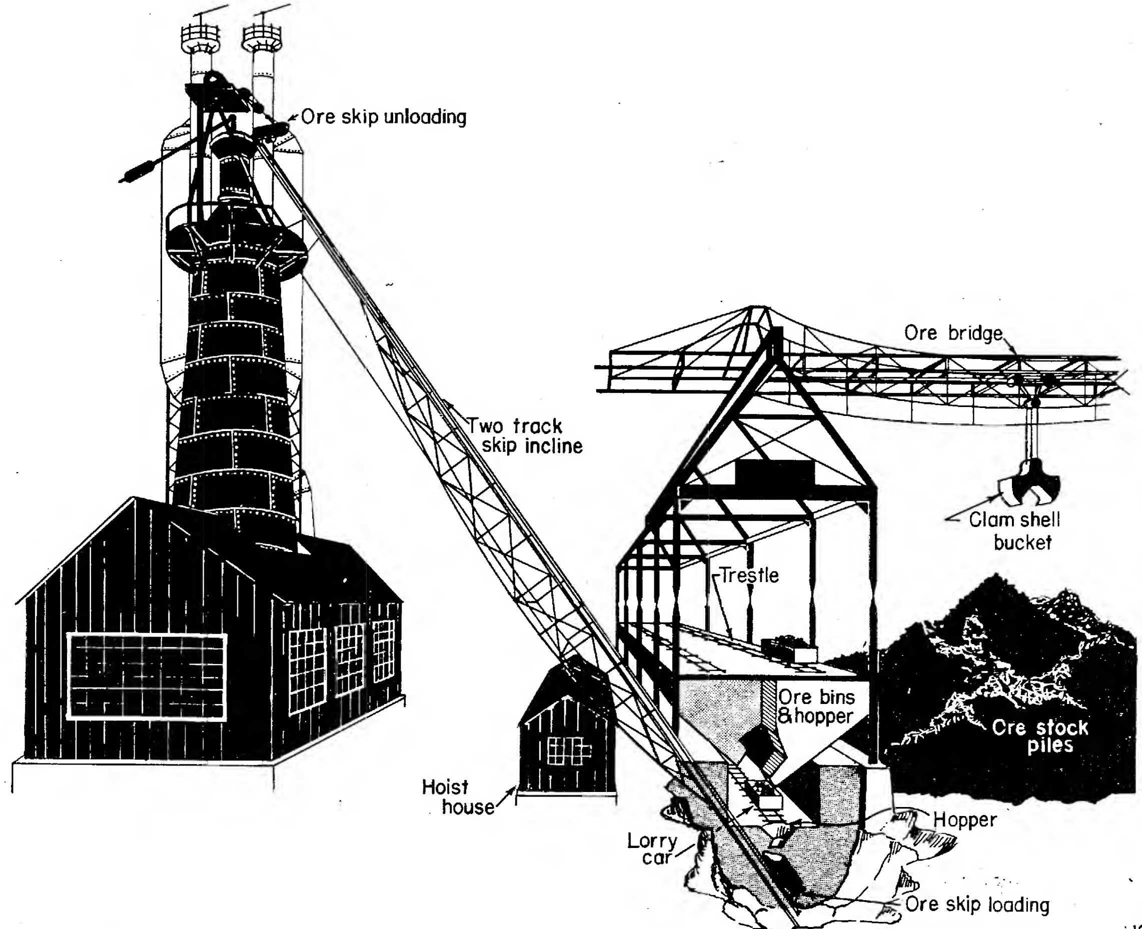
from the large storage piles described above are first picked up in the bucket conveyor on the travelling ore bridge. These bucket conveyors drop the ore and limestone into cars which ride on an elevated platform called the *stock trestle*.

19A

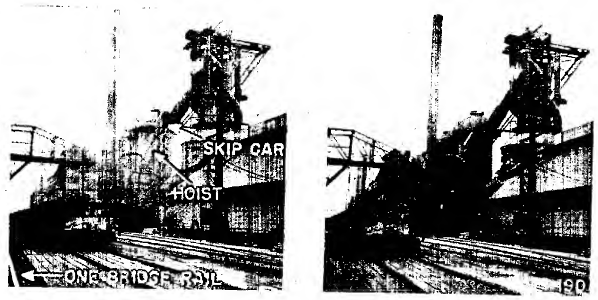
The cars then carry the raw products to the blast furnaces, and dump their contents into bins below the stock trestle.

19B

The minute details of the way in which the raw materials reach the furnaces are of little importance to the interpreter. The drawing to the right illustrates a typical system. In general, the ore and limestone in the ore bins and hoppers are dumped still lower into a lorry car which travels on rails beneath the stock trestle and bins. Then the lorry car carries the material to a platform over the *skip car*, and measures it into the skip. This skip car, or skip, as it is called, is pulled to the top of the furnace up a steep incline called the *skip hoist*, shown in the stereogram to the right. The charge is finally emptied into the throat of the furnace by way of the bell and hopper device mentioned above.



19C



19D

The coke is generally brought in by rail or conveyed directly from the coke ovens, and is charged in the same way as the ore and limestone.

The motors which lift the skip are drawn by electric power. They are located in the hoist house described in Col. C on the next page.

Every hoisting system has two skip cars so synchronized that one is dumping while the other is being loaded. At the top of the next page there is a closeup view of a skip. A steel cable hoists the skip up the incline.

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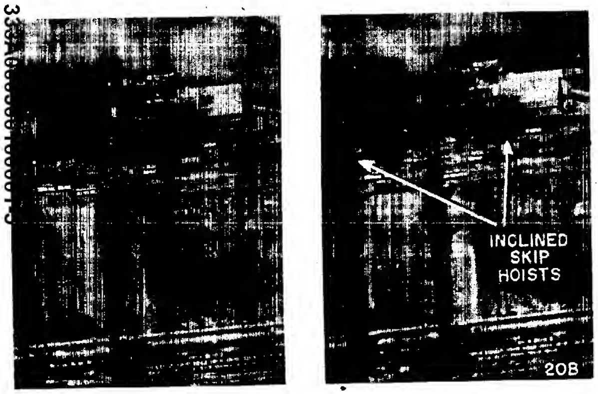
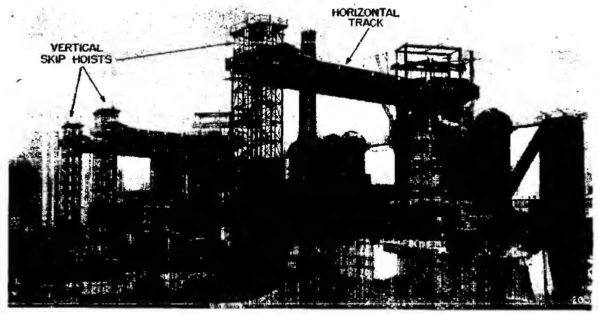
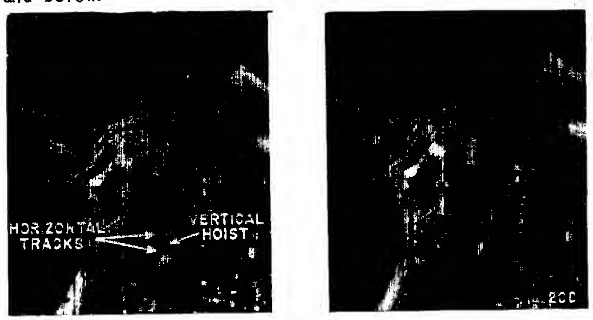
When an *inclined skip hoist* is used, it forms one of the recognition features of a blast furnace. Inclined skip hoists can be readily picked out in good aerial photography.



Vertical skip hoists, which fill the same function as the inclined ones, are used to some extent in Europe and the Far East. The next picture shows three in Kyushu, Japan.

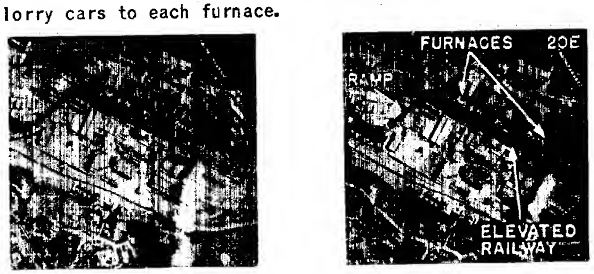


In this type of skip hoist, the skip is carried on a horizontal track from the top of the hoist to the furnace hopper. Often one vertical hoist will serve two or more furnaces; then there will be horizontal tracks from the hoist to each furnace as in the photos above and below.

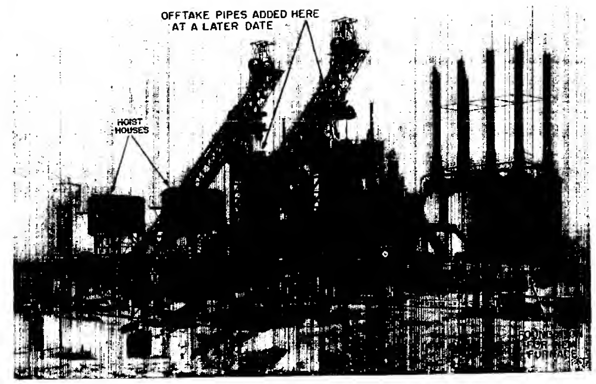


Here three furnaces are fed from one hoist.

A German method which might possibly be duplicated in the Far East eliminates the use of the skip hoist completely. An elevated railway system is substituted, as shown below in the view of the Krupp works at Piene, Germany. Here are seen two elevated tracks, one on each side of the blast furnaces, with long ramps leading up to the charging level. Side tracks carry the lorry cars to each furnace.

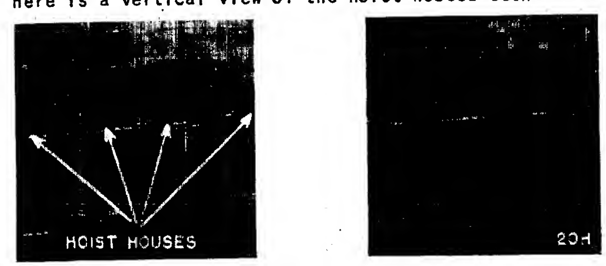


The hoisting of the skip and the working of the hopper at the top of the furnace are directed by the hoist engineer in the *hoist house,* which may be in any one of several locations. In the Far East, the hoist house generally appears to be built on a platform above the lower, or loading end, of the skip hoist as in these at Anshan, Manchuria. This picture was taken



before construction of the new furnaces. If a stock trestle is present, the hoist house may be supported on it. In these cases it may be under the inclined hoist, or built above it as in this view:

Here is a vertical view of the hoist houses seen above.



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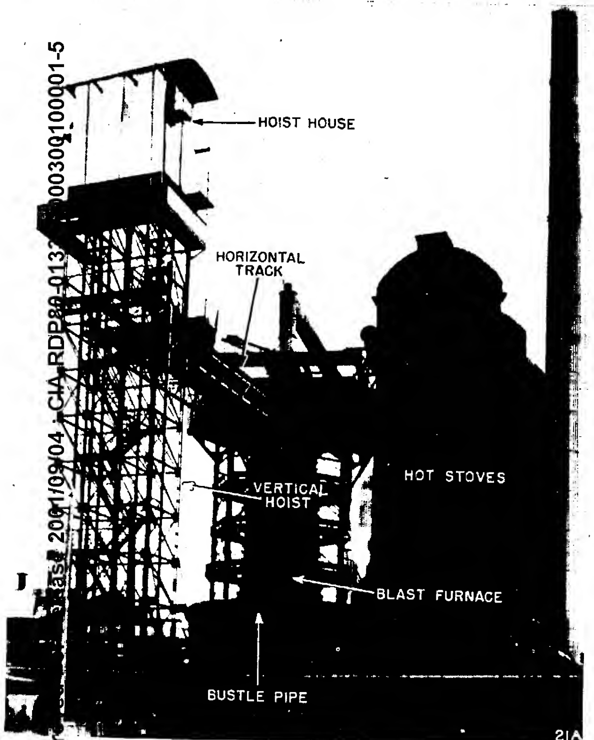
The hoist house may also be placed on the ground under the inclined skip hoist as shown in the drawing on page 19. If the hoist is beneath the trestle, it will be invisible in aerial photographs. Therefore, if the hoist house cannot be seen, it is probably hidden beneath the trestle. When vertical skip hoists are used, the hoist house will be placed at the top of the hoist.



21A

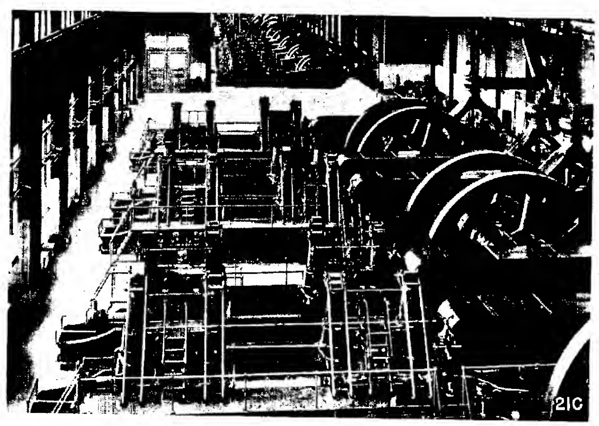
This is how they appear from the air.

21B

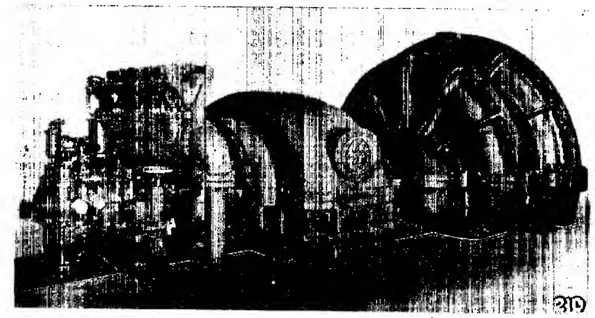
The hoist house is very important. It contains an indicator which continuously records the changing level of the stock-line in the furnace. This tells the hoist engineer when to charge raw materials into the furnace in order to maintain the proper stock-line level. The regularity with which the hoist engineer and the lorry car operator perform their function has an exceedingly important influence on the production of the blast furnace. Thus, the hoist house is a vital control center of blast furnace operation and its destruction would disorganize production.

OPERATION OF BLAST FURNACE: Operation of a blast furnace is continuous; the furnace is maintained at the working temperature 24 hours a day, seven days a week. The constantly replenished charges of coke, ore, and limestone form a column of alternate layers in the furnace. During full operation, the air blast enters through the tuyeres at a pressure of 15 to 18 pounds per square inch and a rate of from 10,000 to 70,000 cubic feet of air per minute. It takes about 14 days to put an idle blast furnace into capacity operation. Furnaces may also operate at reduced blast, or, if necessary, banked and the heat discontinued. During this time, the furnace remains inactive, but it can be restored to full production in about a week. A blast furnace remains in operation for 4 to 5 years, and is closed down only when the firebrick lining requires renewal.

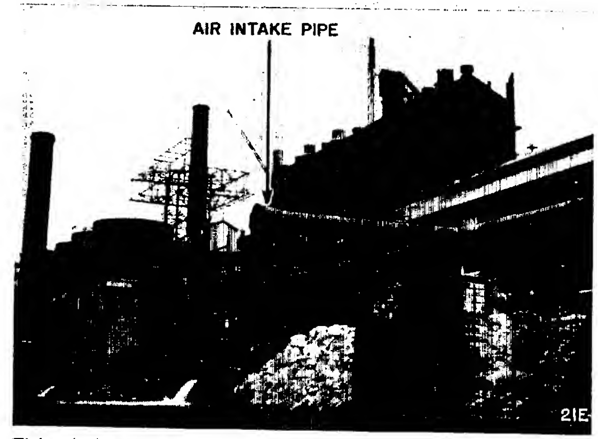
The air blast is created by blasting engines of either the piston type;


21C

or the turboblower type:

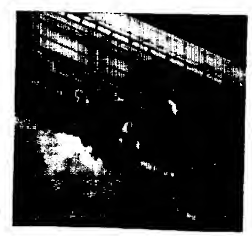

21D

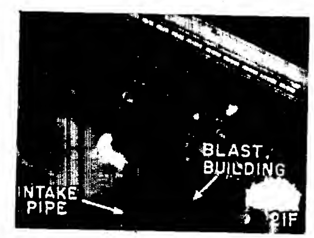
These huge machines are housed in a large building called the *blower house*, which usually adjoins the boiler house, and is near the furnaces. The air is sucked into the turboblowers through a large pipe on the outside of the blower house.



21E

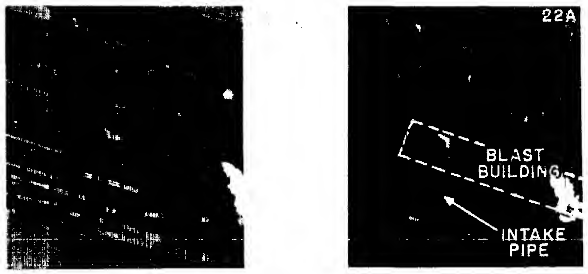
This intake pipe may be distinguished in good aerial photography and will furnish an important clue to the identification of the blower building, which is vital to the operation of the blast furnace. Here is a vertical view of the intake pipe shown above;



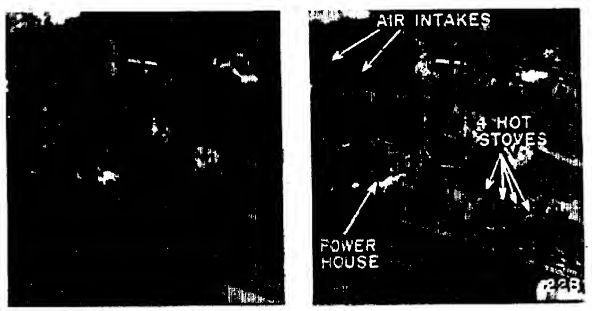


21F

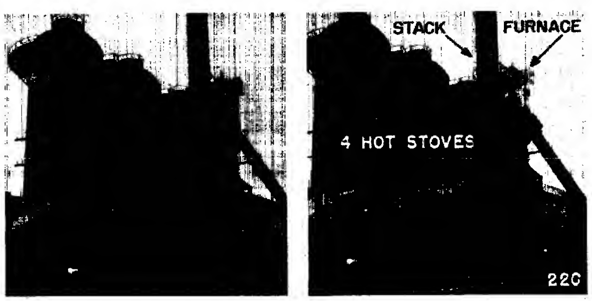
and another similar one in the same plant:



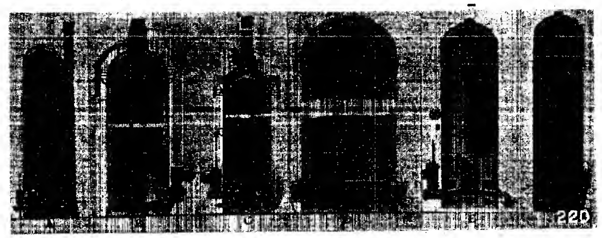
The next stereogram shows a vertical type of intake, which appears square in cross-section.



The air blast must be hot (1200-1400° F) before it enters the furnace. It is heated in *hot blast stoves*, which are large cylindrical structures near the furnace, some 18' to 22' in diameter and 80' to 100' high. Four

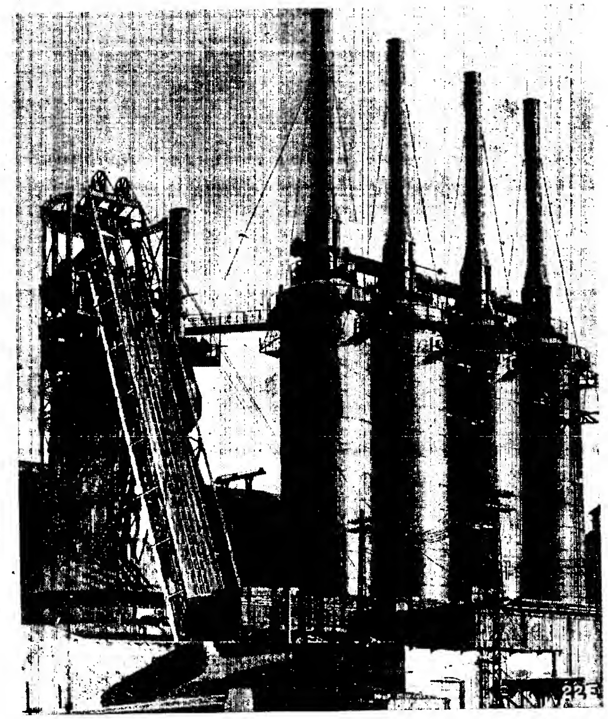


hot stoves are visible in the above stereogram. Usually these conspicuous stoves are the first recognition-mark of a blast furnace. The diagram at top of next column shows several different types in cross section: Type D appears to be most popular.

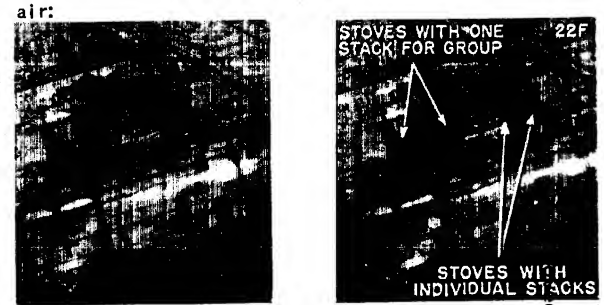


A cross-section of a stove would disclose a central heating chamber surrounded by checker-work brick baffle walls. This firebrick structure is enclosed by a cylindrical steel shell. A part of the blast furnace gases is burned in this chamber and the burning gas is circulated through the stove until the brick work is raised to a very high temperature. The valves are then reversed and the cold air blast is sent through the hot stoves to be heated and then through the tuyeres into the furnace, as previously explained.

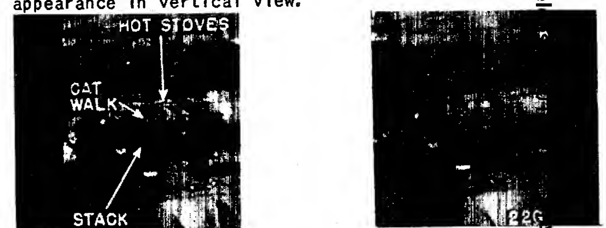
The burned gases go to a stack; each stove may have its own stack, as seen in this foreign smelter;



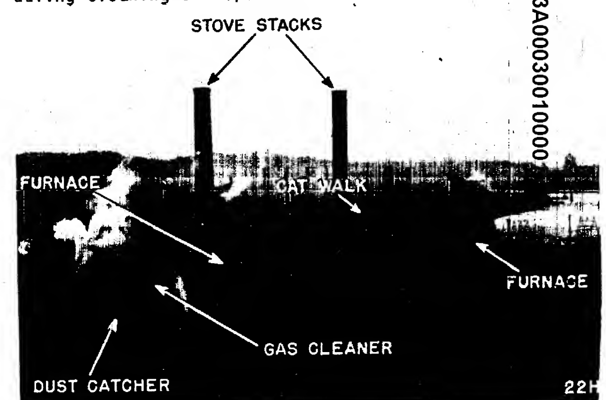
or there may be one large stack serving all of the stoves in one group. This is the way they look from the air:



The presence of the stack or stacks will distinguish the hot stoves from tanks or silos. Sometimes a catwalk runs across the tops of the stoves and confuses their appearance in vertical view.



Each furnace has at least three, and usually four, hot stoves of which one is pre-heating the blast while the others are being heated by burning gas. The cold air blast is changed to a different stove about once an hour. Sometimes an additional stove is present as a standby during cleaning or repairs.



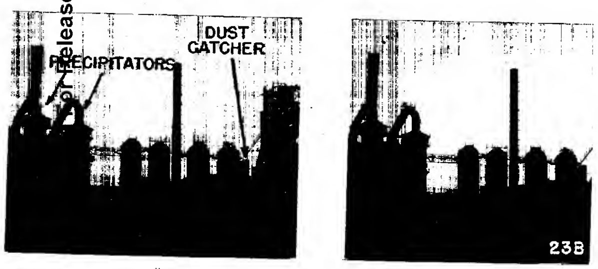
There are four stoves for each blast furnace in the above photo.

The hot air blast enters the furnace and passes wards. The coke burns in the air, generating gases and at which melts the charge and promotes certain chemical actions. The gases formed by the combustion of the oke combine with and remove the oxygen in the ore hile the molten limestone combines with the earthy atter of the ore, forming slag. By the time the air eaches the top of the furnace it includes carbon onoxide, nitrogen, and carbon dioxide, and is now called *blast furnace gas* or *top gas*. This gas then leaves the furnace by large *offtake pipes* which can be seen rising from the top of the furnace.

23A

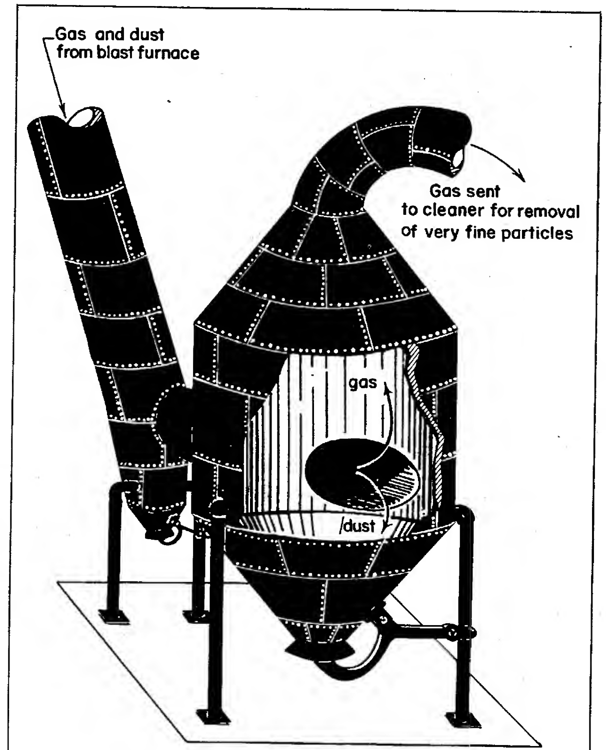
These vertical offtake pipes allow the large dust particles to drop out of the gas. Sometimes offtake pipes are absent in older types.

These vertical offtakes lead the blast furnace gas into two large mains called *downcomers*, which join and run into a cylindrical tank-like contraption, cone-shaped at both top and bottom. This is the *dustcatcher*.



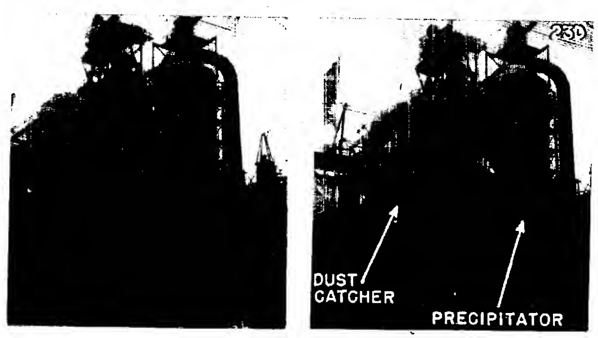
23B

The sketch at top of next column shows the simplicity of its construction. The gas enters on a tangent, swirls about, and leaves at the top. This change in direction of flow inside such a large space slows down the gas and causes most of the dust particles to drop out. In some of the newer type dust catchers, gas may enter at the top and leave at the bottom, but the operation and effect produced are the same.



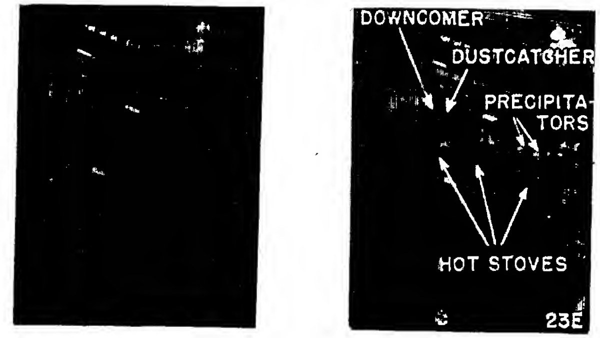
23C

Only the very finest particles of dust now remain in the gas. It is passed through a *Cottrell precipitator*, which removes the dust by electrostatically charging the particles. The precipitator is a large cylindrical tower with shallow conical top. Precipitators may be located close by the dustcatcher:



23D

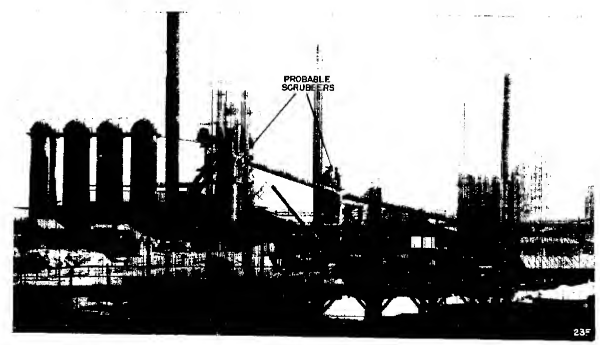
or at some distance from it, as seen in 23B. And here they are shown as seen from the air:



23E

These serve three furnaces. The dustcatcher can usually be distinguished from the scrubbers or precipitators in several ways. The catcher is considerably smaller, and it is located immediately adjoining the furnace. In fairly clear photography, the downcomer pipe can be seen entering the catcher, as shown in the photos above. The clean gas leaves from the tapered top of the precipitator.

An older method of cleaning the gas is by passing it through a fine spray of water in a *scrubber*. After scrubbing, the gas is clean enough to burn in the stoves and coke ovens, but not in the gas motors. Centrifugal *washers* are used to separate out the last traces of dust, making the gas suitable for engine use.



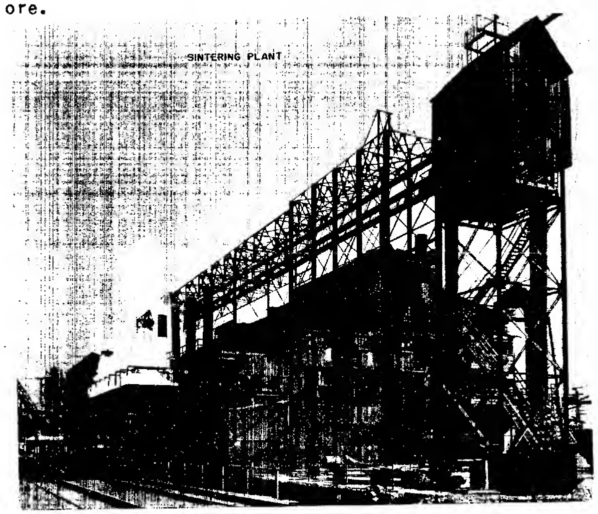
23F

The scrubber and centrifuge method has been replaced largely by the cheaper and more efficient precipitator.

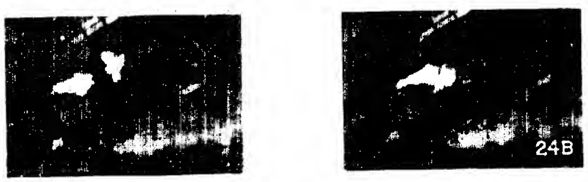
The dust which is removed from the gas consists largely of fine iron particles, and so is worth saving. In modern plants it is reclaimed by *sintering*. In the

RESTRICTED

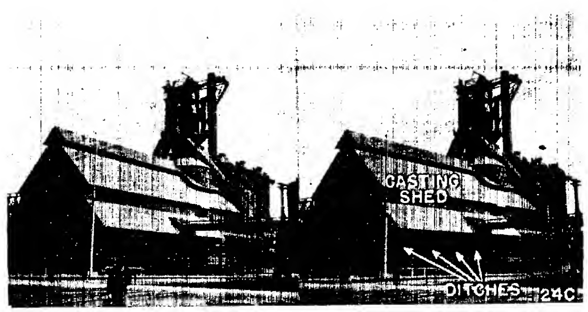
sintering plant, the dust is heated in shallow grates until it is partly fused or clinkered, and then used as ore.



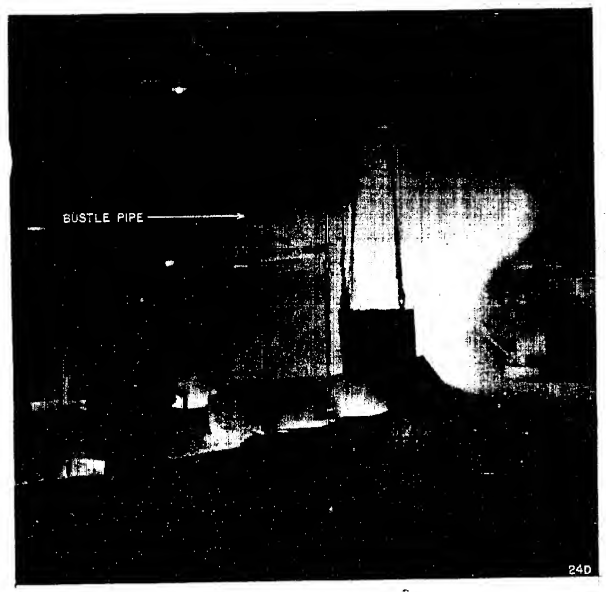
This is a domestic sintering plant. A vertical aerial stereogram of the same building is shown below.



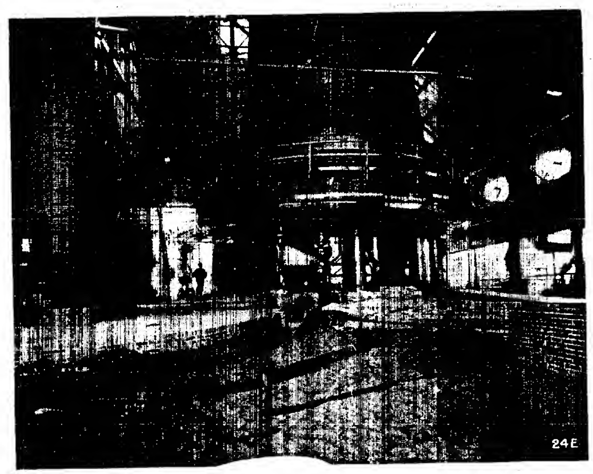
TAPPING THE FURNACE: At intervals of several hours, the molten iron which has accummulated in the hearth of the blast furnace is drawn off from below. This takes place in the *casting shed* which surrounds the base of the furnace. Here is a large casting shed:



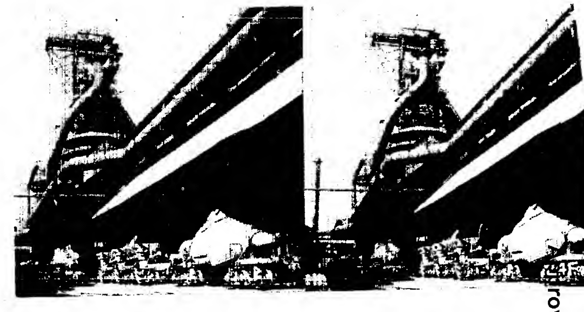
This is called *tapping a heat* and produces a very picturesque pyrotechnical display, as shown below:



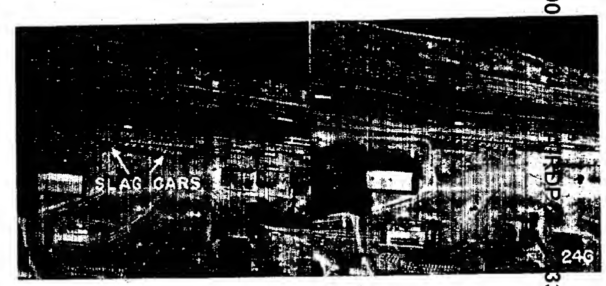
Ditches in the floor of the shed guide the white hot metal as it flows into *ladles*. The ends of the ditches can be seen over the ladles in Fig. 24C. The photo below shows the ditches, themselves:



Two types of ladles are shown below:

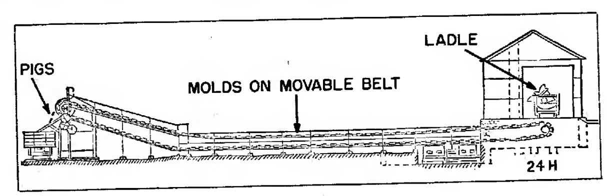


Here, the open type is seen in the background with molten iron pouring into it. It holds only 25 tons. In the foreground is the newer 70 and 100 ton closed type, called variously *submarines*, *pigboats*, or *mixer ladles*. These will keep the iron molten for 24 hours or longer. The open ladles have a distinctive appearance resembling a string of beads, in vertical view:



After being poured into the ladle, the molten iron is disposed of in one of two ways. It is most likely to be carried directly to the open hearth or converter buildings, and kept molten in the pigboat to be used as needed for making steel.

When there is a surplus supply, however, it may be taken to the *pig casting building* and poured into small molds mounted on a movable belt as shown here.



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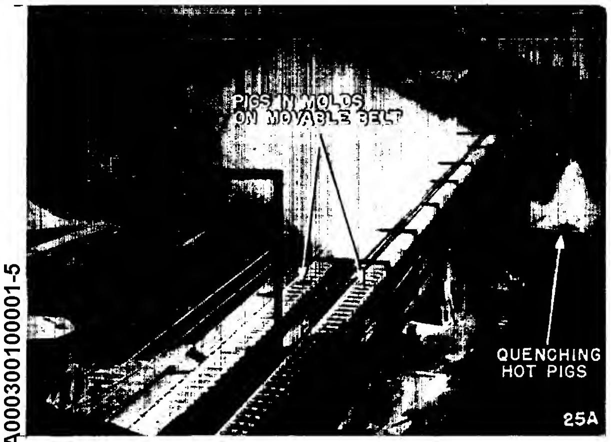
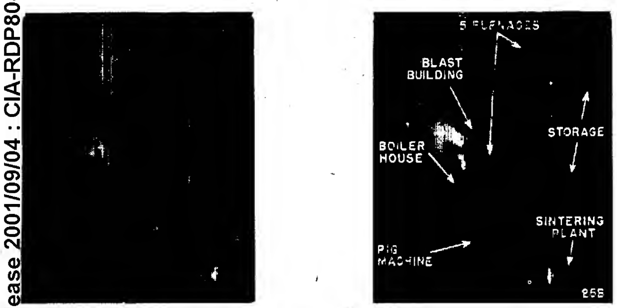
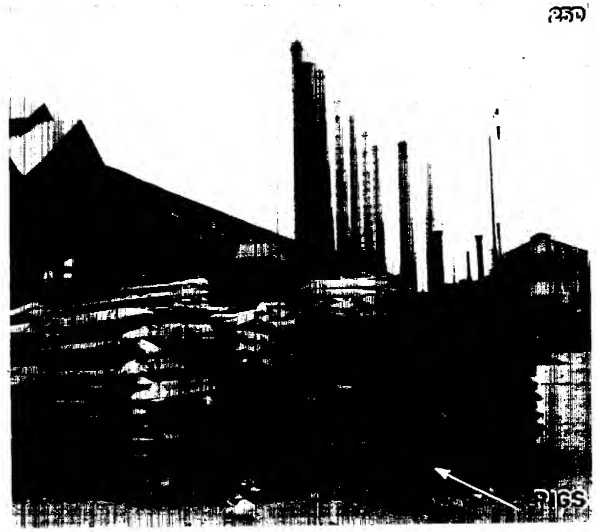


The next photo is an oblique view of a pig machine:



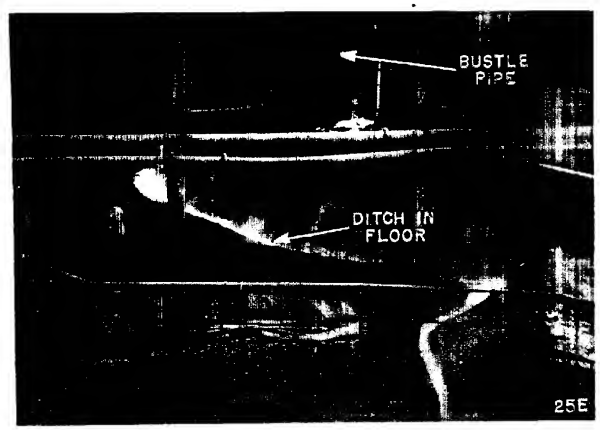
and here is a vertical view of the same machine:

The molten metal is poured into the molds at the low end of the conveyor belt in the shed, and is dropped out at the upper end, where it is cooled by pouring water on it. The steam formed by this cooling can be seen in the above vertical stereogram. When the metal solidifies it is known as *pigs*, and is stored until needed.



Thus, if blast furnace production is interrupted, a reserve supply of raw metal is available which can be melted up and used to make steel until furnace operation is resumed.

The *slag*, a comparatively worthless by-product, is tapped in the same manner from the opposite side of the furnace and removed in smaller ladles to be dumped.



Slag dumps are generally very large. Slag has a clinkerish appearance and is fairly light in color. Near the slag dump there is frequently a slag crushing plant which turns the slag into aggregate for concrete, ship ballast, and rock wool insulating material. The slag dump shown in stereogram below serves three blast furnaces.

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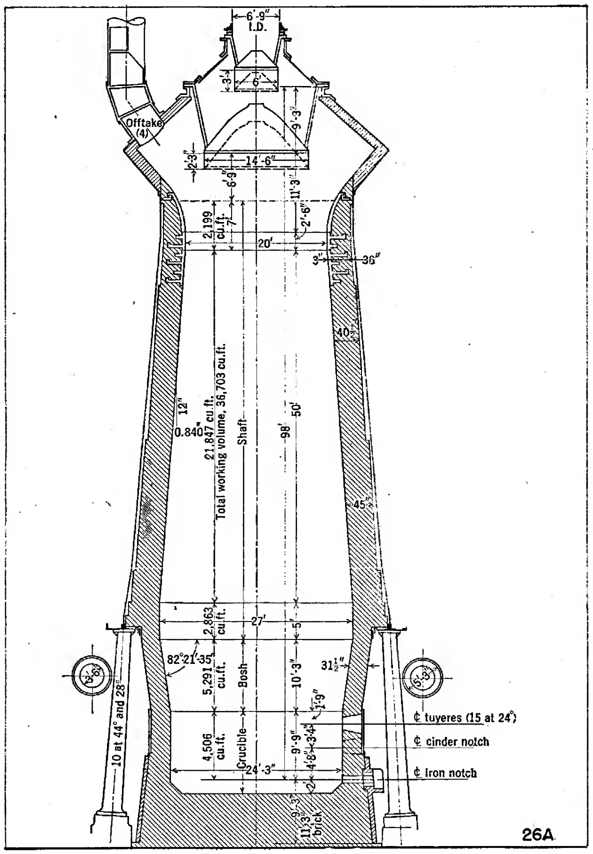
PRODUCTION CAPACITIES: Blast furnaces in Japan and Manchuria are reported to have capacities ranging from 20 to 1,000 tons per day. Only a few furnaces will be found at the extremes of this range. The greatest number of Far Eastern furnaces will be within the 400 to 600 ton group; 500 tons per day probably represents the average production. Although blast furnaces of varying capacities will be found within the same plant, the figure of 500 tons multiplied by the number of furnaces present will be a likely estimate for the daily capacity of a given plant.

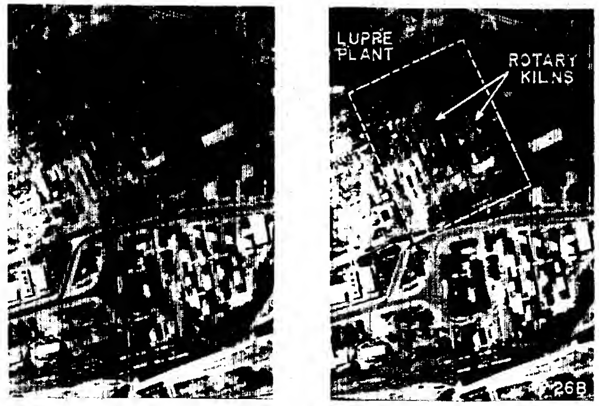
The vertical cross section below gives the main comparative constructional details on dimensions of a modern blast furnace of large capacity (about 1000 tons/day).



26A

B. OTHER IRON PROCESSES

By-passing the blast furnace in the making of iron for steel manufacture has occurred commercially to only a very limited extent. The Japanese produce a small amount of iron in equipment other than blast furnaces, such as rotary kilns, as shown below at Anshan. This iron is also utilized for steel making. It is in the form of "sponge iron", called *Luppe*. Up to the present time, however, iron production by this means is not considered sufficient to affect appreciably the vital position of the blast furnace in the Japanese iron and steel industry.

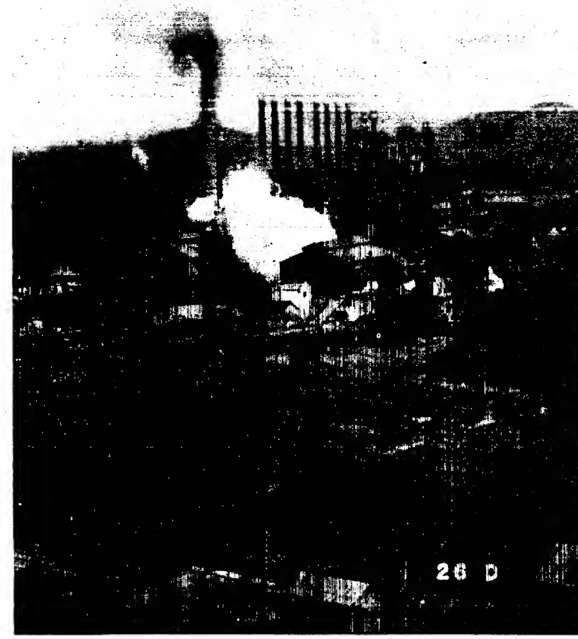


26B

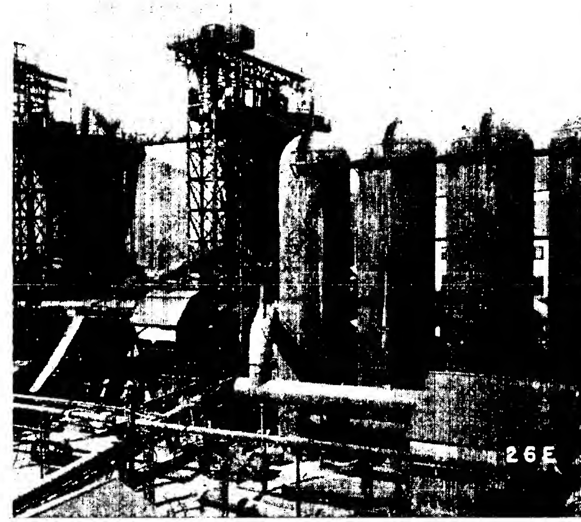
EXAMPLES OF JAPANESE BLAST FURNACES:


26C

Hokkaido, Japan


26 D

Kenjiho, Korea


26E

Honshu, Japan

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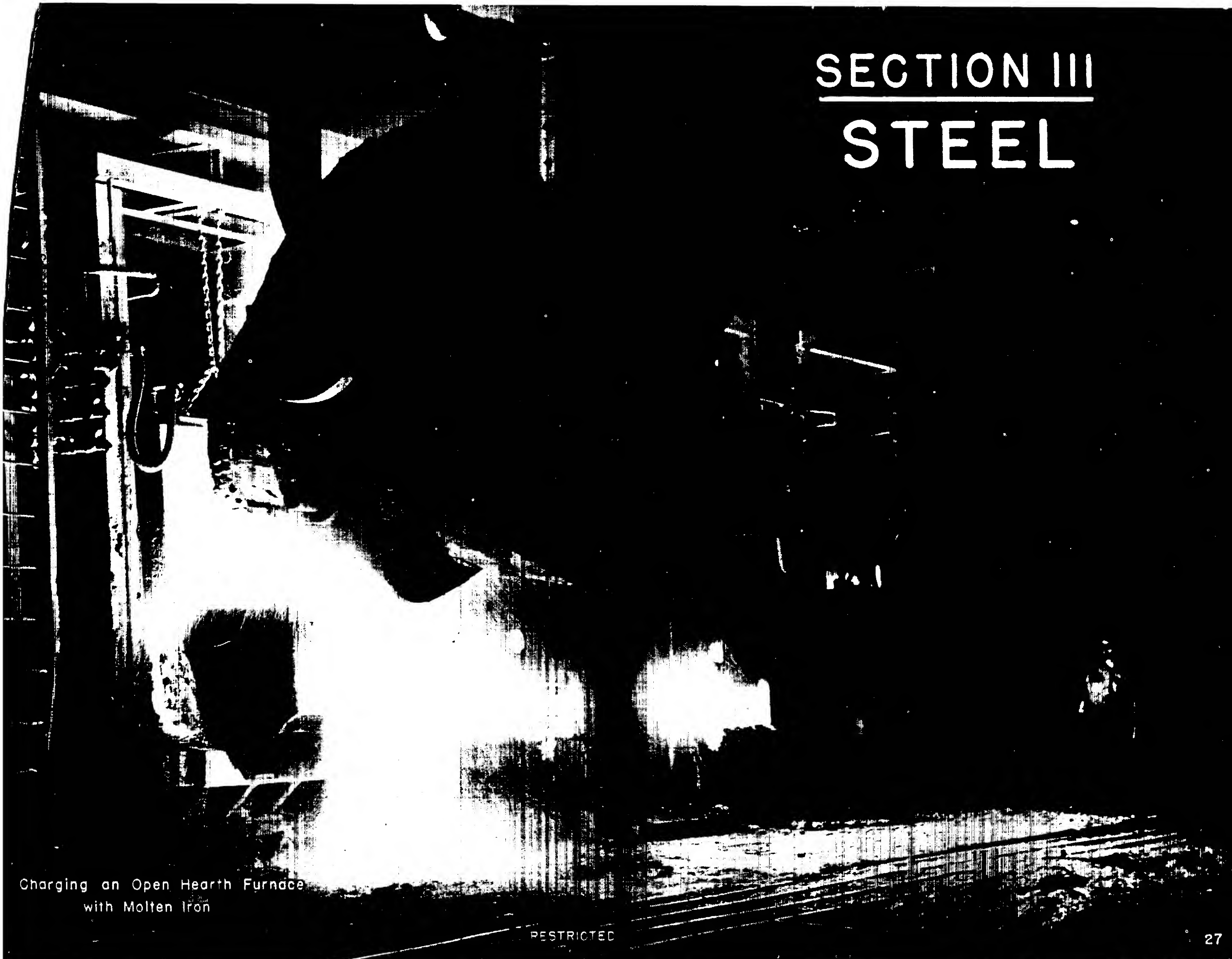
SECTION III
STEEL



Charging an Open Hearth Furnace with Molten Iron

IMPORTANCE OF PRODUCT

Steel in its simplest form is a malleable alloy of iron and carbon, capable of being hardened, toughened and otherwise altered in physical properties by suitable heat treatment. Steel is the most durable metal which can be economically produced in great quantities. Guns and other weapons, armor plate, girders, rails, pipe and tools necessary for the precision instruments of modern warfare could never be produced without steel and its alloys.

RAW MATERIALS

1. *Pig Iron*
2. *Scrap*
3. *Limestone*
4. *Alloying Materials*

These are the raw materials which are normally used in the making of steel. The *pig iron*, which may be either in molten or solid form, is the basic ingredient. *Scrap* iron or steel serves to dilute the impurities in the pig iron and shortens the operation. The *limestone* acts as a flux. *Alloying materials* such as nickel, chromium, tungsten, vanadium, etc. are added to the steel to influence the physical and chemical properties. Among such properties are hardness, toughness, tensile strength, malleability, ductility, resistance to corrosion, thermal expansion, and magnetic permeability.

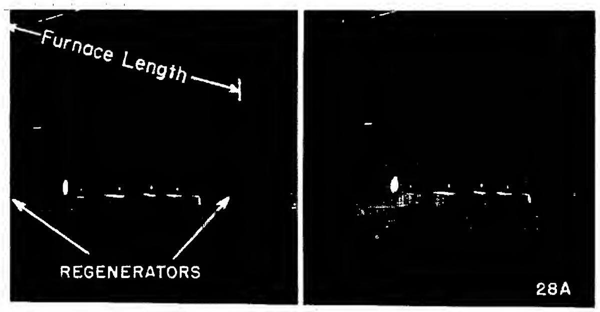
Steel produced in a Bessemer converter may also be used as raw material for further processing.

PROCESSES USED

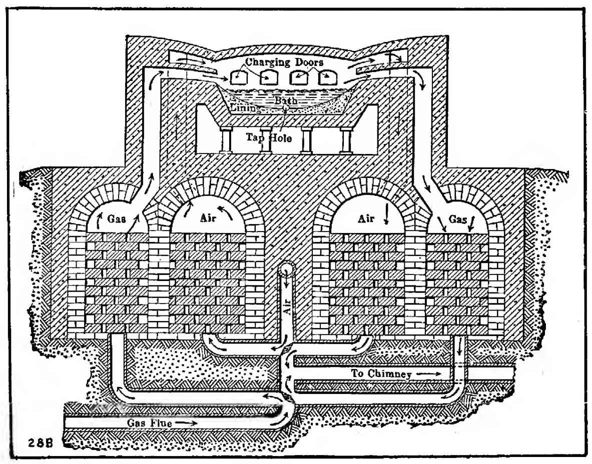
In order to make steel, the pig iron must be freed of its impurities, and small amounts of the alloy ingredients mentioned above must be added. The most important process for the production of steel is the open-hearth, followed by the *Bessemer*, *electric* and *crucible* processes. The crucible process, however, will not be considered in this Study because it produces only a very small amount of steel and its use by the Japanese is negligible.

A. OPEN HEARTH PROCESS

The open hearth furnace is a fire-brick structure entirely enclosed in steel plates and bound together with structural beams and tie-rods. This brick and steel construction can be seen in the stereogram below, which shows the charging side of a typical furnace.

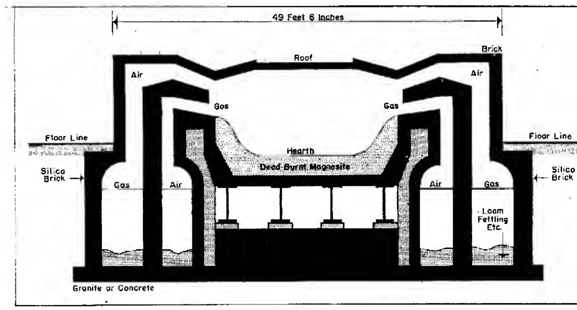


The following sketch shows how the above furnace would look if the steel, brickwork, and flooring were removed:

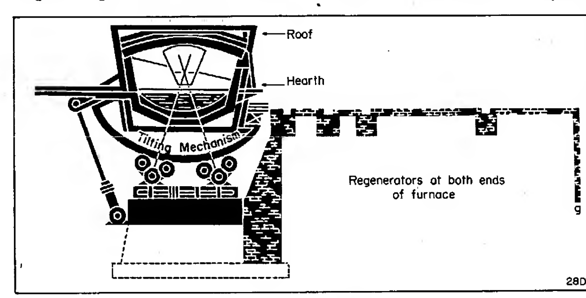


It shows the relationship between the three main features which form the furnace; they are the hearth, the roof, the regenerators. This diagram is a longitudinal section of the furnace.

The *hearth* is sometimes called the "bottom" and is nothing more than an overgrown soup dish of the shallow type. The word "overgrown" is used unreservedly because an average hearth will measure about 50 feet in length and 15 feet in width. It is lined with special kinds of heat-resisting brick; the variety of brick used depends upon whether the furnace is the acid or basic type. The impurities in the pig determine the type of lining used. Furnaces are built with either (1) stationary hearth or (2) tilting or rolling hearth. The stationary hearth is supported by steel "I" beams, while the other rests on rollers which make tilting possible. The simplified diagram below shows the stationary type hearth with its roof and *regenerators*.



Built in front of the furnace and under the charging floor are two pairs of regenerators which preheat the gas and air for combustion. These are elaborate brick constructions forming such an intricate pattern that they are called "checker-board". The hearth is covered by an arched brick-work which forms the *roof* of the furnace. Now, here is how the hearth-roof-regenerator combination would look if it were cut at right angles to the direction shown in the above diagram.



This cross-section is taken through the center of the furnace and, therefore does not cut either of the regenerators, both of which are located at the ends of the furnaces. A tilting type furnace is pictured here.

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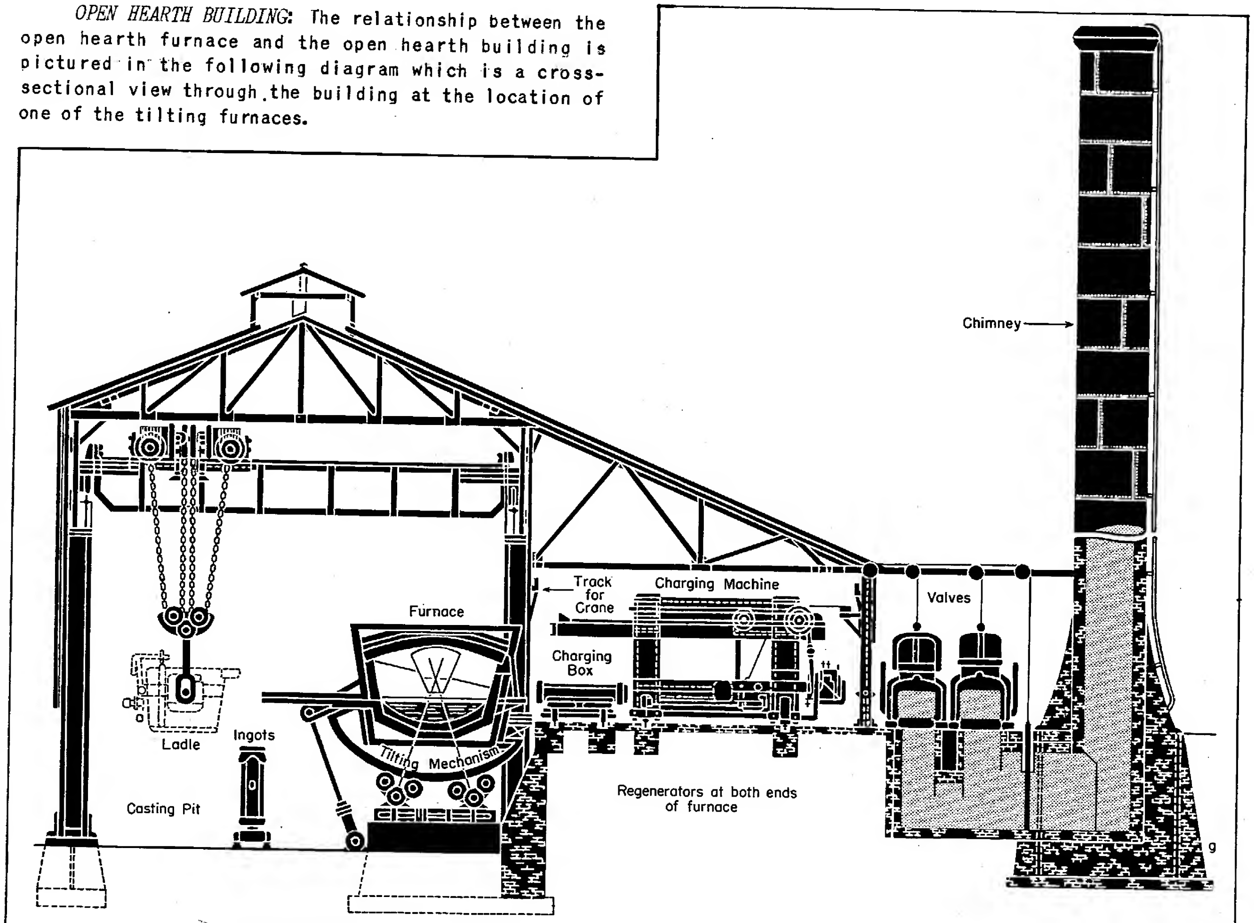
OPEN HEARTH BUILDING: The relationship between the open hearth furnace and the open hearth building is pictured in the following diagram which is a cross-sectional view through the building at the location of one of the tilting furnaces.



29A

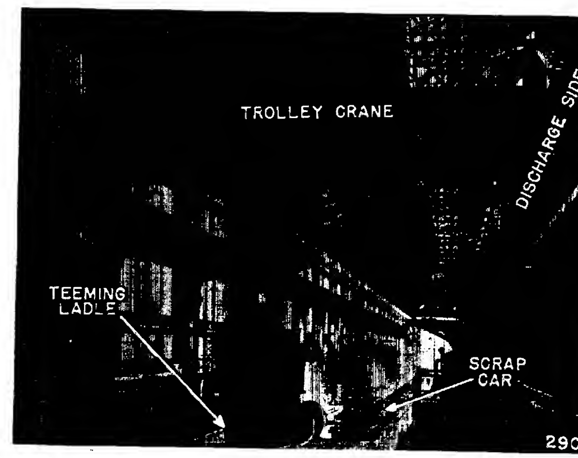
The building in which the open hearth furnaces are housed is universally typical and readily distinguishable from other buildings in the plant layout. It is generally the longest of all the surrounding structures, the length varying with the number of furnaces. Normally, the average open hearth building will be several hundred feet long, the length always being much greater than its width. As shown in the above diagram, the furnace forms the center of the open hearth building layout.

On the same level as the hearth, and in front of the furnace is the *charging platform* or *floor*. The solid chemicals to be used as fluxes, alloying ingredients to make the steel and the materials for repairing furnace bottoms are usually weighed out and spread on this platform. The photo at top of next column shows the front of the furnaces and the raw materials piled upon the charging platform. Tracks, both wide and narrow gauge, are also on the platform and carry the charging equipment. One type of charging truck can be seen in the background. The space over the platform may be spanned by one or more electric cranes.

A *mixer*, which is a huge ladle, capable of holding 150 to 1,300 tons of hot metal, may be located at one

end of the charging floor. The mixer acts as a reservoir for molten metal from the blast furnace and sometimes from the Bessemer. It preserves the heat and produces a uniform mixture. The newer types are cylindrical form.

Behind the furnace is the *casting pit* with permanent stands for the casting or teeming ladles where they are supported on trunnions. The casting pit, which is shown at the extreme left side of diagram 29A, contains tracks for the ingot cars which carry the ingot molds. There are also tracks for standard gondola cars which refuse and scrap can be placed, but these tracks are not shown in the diagram. This portion of the open hearth layout is clearly shown in the photo below.



29C

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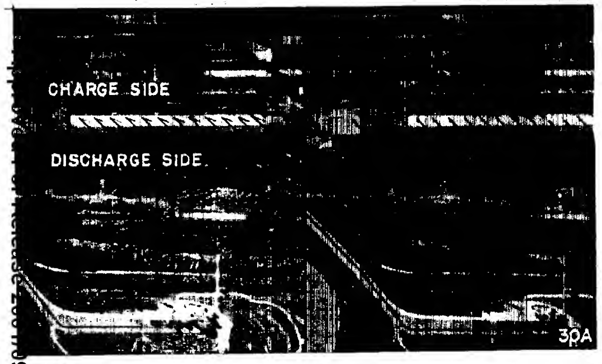
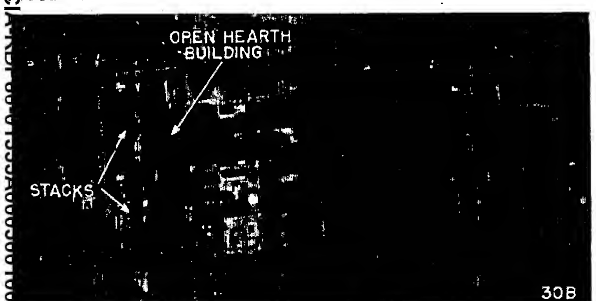
The above two photos give a good idea of the sturdiness of the interior construction.

Each furnace has its own stack. The stacks from all the furnaces in one open-hearth building are placed along the edge of the building on the charge side so that they can draw off the waste gases from the regenerators.

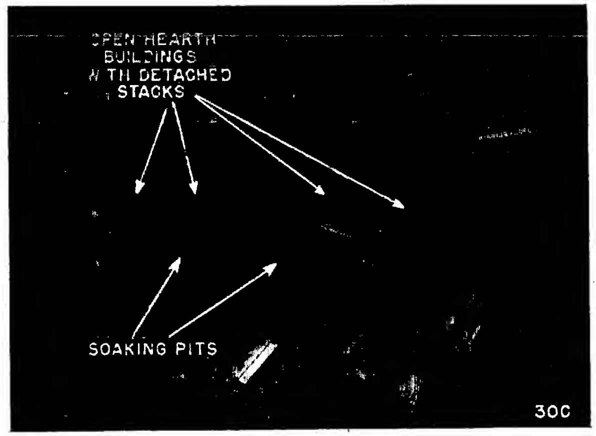


Often they are set a short distance away from the building giving the impression that they are separate installations.



There may be a long low shed between building and stacks housing the inlet and outlet valves of the regenerators. This shed can be seen just to the left of the stack in diagram 29A.

The furnace stacks of the open-hearth building constitute a most important identification feature. By referring to the stack, the interpreter usually may be able to determine the layout of the interior of the open-hearth building and to decide which installation has been hit if the building is bombed. The following is an aerial oblique of a series of typical open-hearth buildings with long rows of stacks.



Each stack represents a furnace. This fact comes in handy when trying to determine the total approximate productive capacity of the open-hearths as discussed below.

The type of roof over the building varies greatly. Several types will be observed in the illustrations herein, especially in the section of annotated photographs. A favorite type is the "lean-to" shown in diagram 29A. It will be noticed that the building does not have a symmetrical cross-section, the charging side being wider. This lack of symmetry can be noticed in the open hearth building on extreme left in the last photograph.

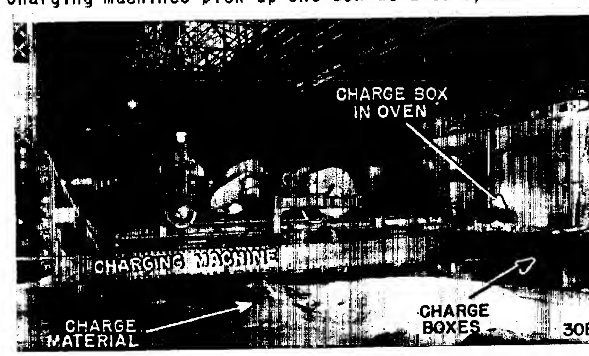
OPERATION OF OPEN HEARTH: The open hearth furnace operates upon the principle of indirect heating. The gas and air pass through the heated brick work on the intake side of the regenerator. The gas and air come together in the open space between the hearth and the roof where it is ignited and deflected down to the charge on the hearth as shown in 28B. The waste gases are carried away through the outlet port at the opposite side of the hearth, then to the stack. The waste hot gases heat up the bricks in the regenerator before entering the stack. At the same time, the bricks of the intake regenerator are giving up their heat to the air and gas going into the hearth. The direction of the flow of gas is changed by means of a reversing valve so that the incoming gas and air are then passed through the heated portion of the regenerator and waste gases flow through the cooled regenerator. The reversal takes place at least once in every 30 minutes.

The selection of fuel to be burned in the furnace depends upon the locality of the plant and the cost of the fuel. This list of possible fuels includes natural gas, producer gas, fuel oil, tar, coke-oven gas, and powdered coal. Coke-oven gas is most extensively used. Producer gas is next in importance and may be made from coal at the plant. Fuel oil in the Far East is scarce and usually must be shipped over long distance. Powdered coal can be used but is not too desirable.

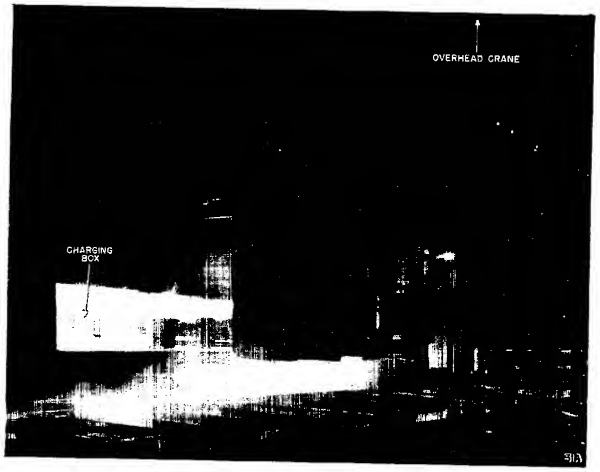
CHARGING THE FURNACE: The furnace is charged from the charging platform or floor through the oven doors which conceal the hearth.

An observer, standing on the floor of the open-hearth building is actually on a level with the middle of the furnace. The view in this stereogram shows what the observer would see from the charging floor. One pair of regenerators is underneath the observer and charging floor.

The furnace is charged with both liquid and solid materials. The solid charge is composed mostly of steel scrap and iron pigs. Limestone flux is also included in the charge to lower the melting point of the mixture. These materials are brought to the front of the furnace in charging boxes which are loaded on small flat cars. Charging machines pick up one box at a time, and



move into the furnace where the box is turned over and emptied. Overhead cranes may also be used for charging the furnace. In the next view, the crane is shown inserting a charge box into the furnace.

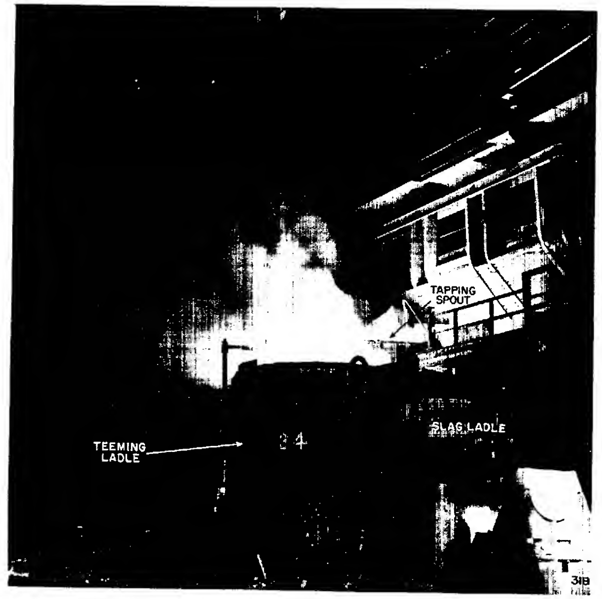


The rails, but not the overhead crane, are shown in Fig. 29A.

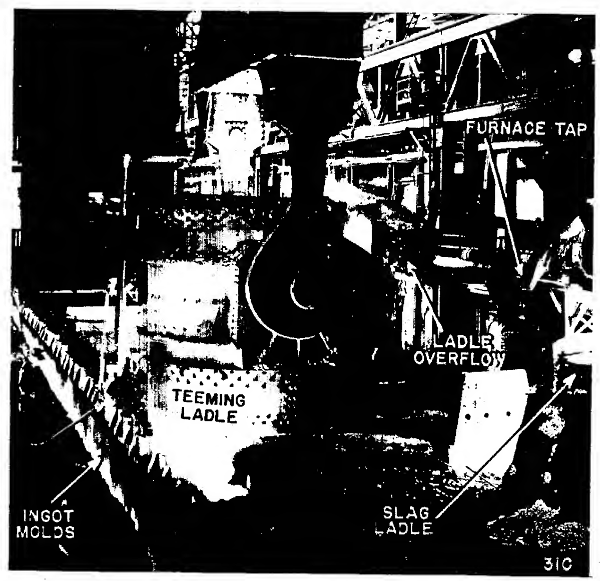
The liquid charge of molten metal is poured from the mixer into large ladles as needed. The ladle is usually carried to the furnace by crane and the metal poured into the furnace, using a removable trough. See Fig. 29A and page 27.

The molten charge may be a mixture of pig iron and steel from the Bessemer convertor or electric furnace. When the liquid charge is from two different sources, the method is called a *duplex process*. By using blast furnace pig and Bessemer steel in the open hearth the production is greatly speeded up because the mixed charge does not have to remain in the open hearth furnace as long as would a charge of pig iron alone.

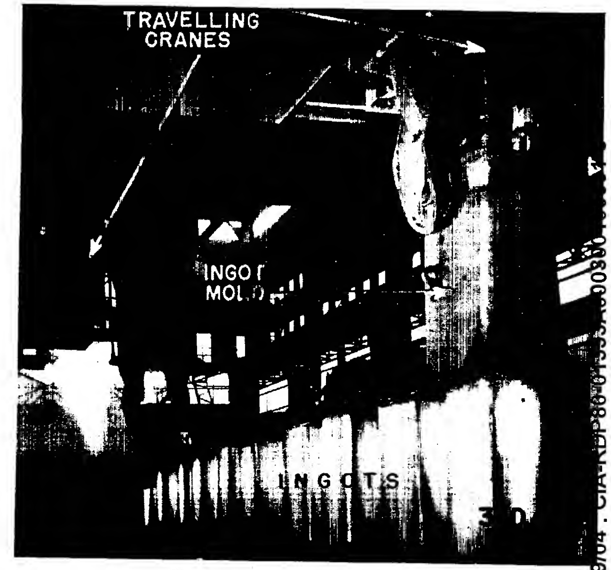
TAPPING THE FURNACE: At the completion of the steel making operation the liquid metal is tapped, or poured into the *teeming ladle* which usually has a capacity of 125 tons. The ladle has an overflow spout which allows the slag to pour off into an adjacent smaller ladle. In the view at the top of the next column, a furnace is being tapped and the metal is flowing into a ladle. The slag has not yet overflowed into the slag ladle.



The teeming ladle is carried to the *ingot cars*, where the steel is allowed to flow into the molds through a nozzle in the bottom of the ladle.



After *ingots* are teemed, or cast, they will solidify within a half hour. They are then transferred to the stripping house where the molds are removed. The ingots are left on the cars which carry them to the rolling mills for fabrication.



PRODUCTION CAPACITIES: There is some variation in the productive capacity of open-hearth furnaces. Although most furnaces will produce between 150 to 250 tons of steel a day, some furnaces are rated at much below the 150 ton figure and few above 250 tons. In estimating the total capacity of all the open hearth furnaces in a steel plant, a close approximation can usually be made by assuming the daily production from each furnace as 200 tons and multiplying this figure by the number of stacks on all of the open hearth buildings. The greater the number of open hearth-furnaces, the more accurate will be the resulting capacity estimate.

RECOGNITION FEATURES: Open hearth building will be long and narrow, its length usually about ten times its width. When roof is a simple gable, one side will be long and terminate close to the ground, resembling a lean-to and giving the impression of an unsymmetrical building; long row of stacks placed at equal intervals along lean-to side; stacks may be attached to buildings or be placed in a row a short distance from, and parallel to the building. In exceptional cases, only a few open hearths may be present, so the building may be short.

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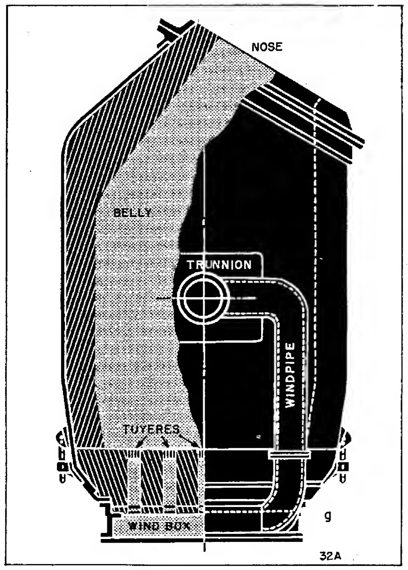
BESSEMER PROCESS:

The furnace used in this process is called a *Bessemer converter*. It is a very large cylindrically-shaped vessel having an average diameter of 11 feet and height of 18 feet. The converter, which consists of a riveted steel shell, is supported by two trunnions upon which it can be made to revolve.



One of these trunnions is hollow and serves as a windpipe to connect the blast from the blowing engines with the wind box at the bottom of the vessel. On the other trunnion is fastened a pinion by which the converter can be revolved through an angle of at least 270 degrees. A thick wall of refractory brick lines the walls and bottom of the converter. The bottom lining is pierced with 250 half-inch holes, called tuyeres, which connect the wind box with the inside of the converter. These serve as passage for the blast.

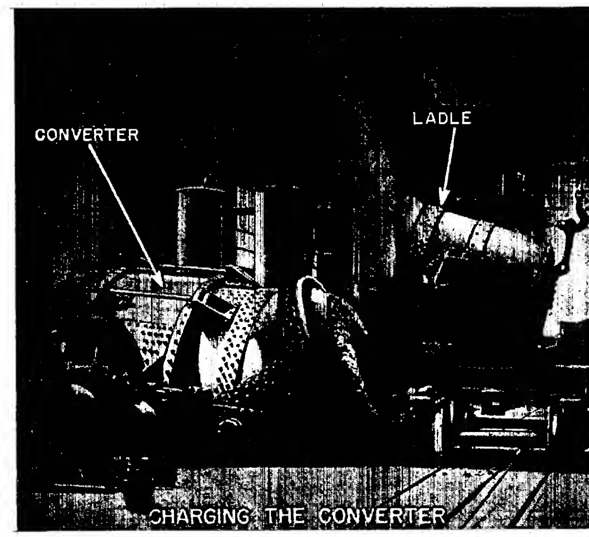
Just outside the converter house is the *blowing room*. Here are located the engines which create the blast for the converters.

OPERATION OF THE CONVERTER: Mechanically, the Bessemer process is very simple. A blast of hot air is blown through the tuyeres into the mass of molten pig

THE "BLOW"

iron which has been poured into the converter. This purifies the iron and, by adding certain ingredients at the end of the "blow", steel is produced.

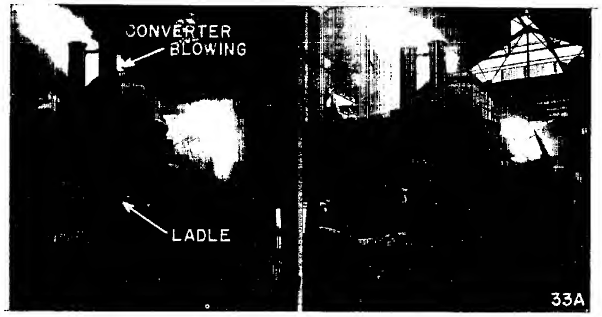
CHARGING THE CONVERTER: The converter is rotated until it is lying on its side. The liquid pig iron from the blast furnace is poured into it.



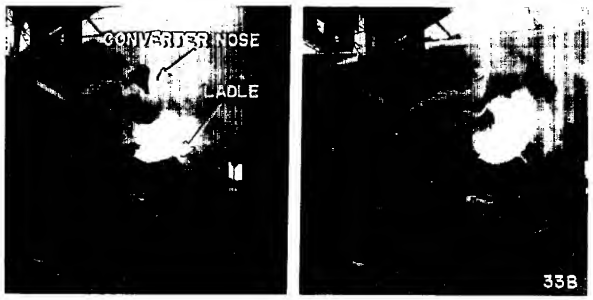
CHARGING THE CONVERTER

The blast is then turned on and the converter turned to an upright position. If cold scrap metal is added it will be placed in at this time. The blow continues for about 15 minutes during which time a great column of flame and smoke blows out of the converter. The flame from the blow is great -- often reaching 30 feet or more above the nose of the converter.

TAPPING THE CONVERTER: After blowing for approximately fifteen minutes the converter is turned down on its side again and the blast cut off. The charge is poured from the converter's nose into large ladles set on a railway chassis. The metal which is poured into the ladle may be teemed into molds to form ingots in the same manner as in the open hearth. If the duplex process is being used, part or all of the steel may be carried to the mixer on the charging floor of the open hearth. The next two views show the ladle and the pouring of the metal.



33A

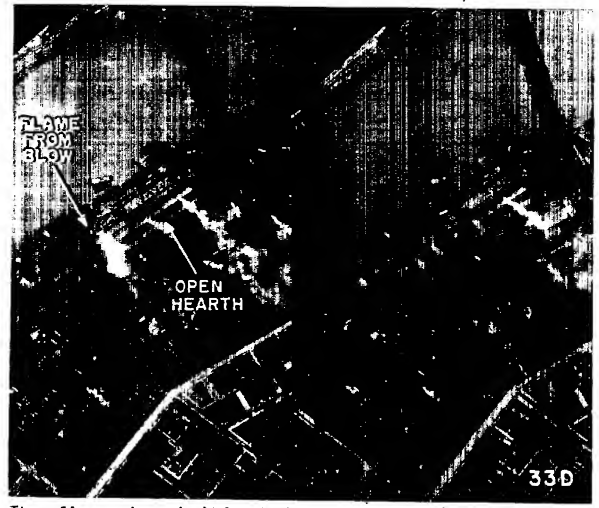


33B

BESSEMER BUILDING: The converters are usually housed in the open hearth building or in adjoining building. Because of the obnoxious fumes and tremendous heat thrown off with the flame of the blow, the roof across the entire width of the Bessemers is normally cut away. This permits the flame to project through this hole in the roof of the building as shown below:

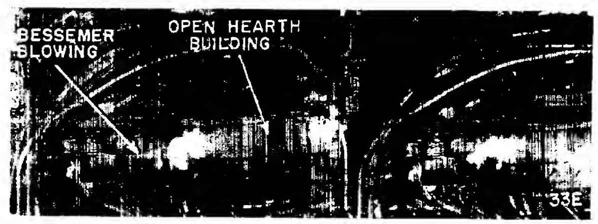
33C

Here is the same Bessemer building in vertical view as seen a few minutes later:



33D

The flame is visible but some smoke is also being produced. The opening across the entire width of the roof will indicate the position of the converters. However, this opening may be obscured by great clouds of brown smoke when the Bessemer is blowing, as in this view:

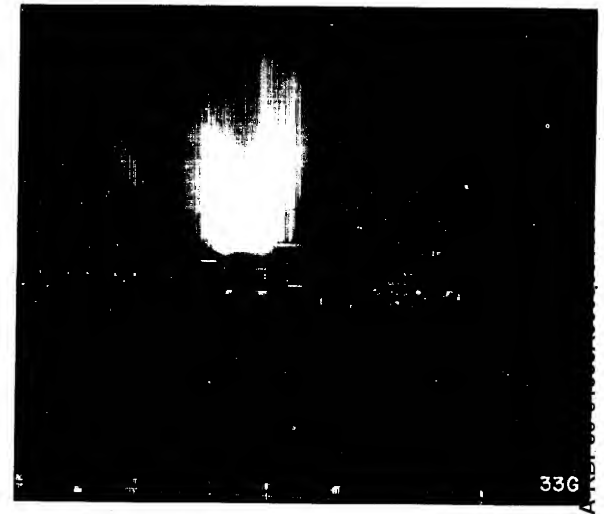


33E

This smoke is one of the features which will identify the Bessemers for the interpreter. Here is a ground stereogram of the Bessemer shown above.

33F

At night the converter blow is a landmark which can be seen for many miles illuminating the sky with a brilliant orange glow.


33G

It is reported that some Far Eastern steel plants have constructed shields or hoods over each Bessemer to reduce the visibility of the flame. The following photograph shows a building adjoining the open hearth building in a German steel plant which is reported to contain three Bessemer converters under hoods.


33H

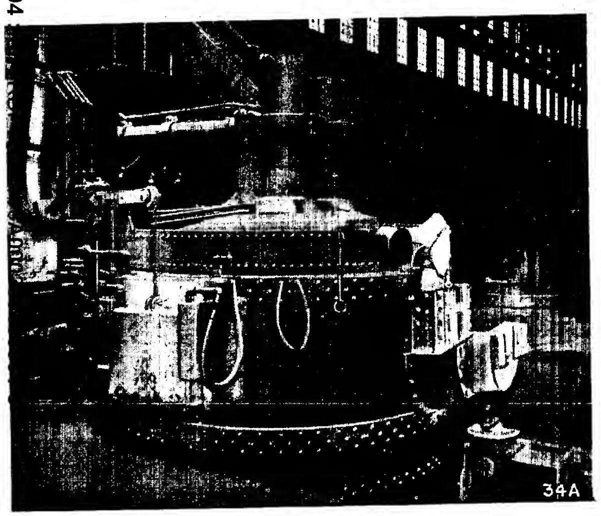
Two auxiliary structures are associated with the converter building: (1) the blowing room, mentioned on the page opposite, and (2) the *bottom house*, in which burned-out converter bottoms are regularly repaired. A lean-to at one side of the bottom house contains ovens for drying the wet refractories used. Overhead cranes load the bottoms into trucks or buggies which carry them between the bottom house and the converter building. These features may assist in identifying Bessemer installations. A bottom house is shown in the annotated examples, and the buggy track is plainly seen.

PRODUCTION CAPACITY: Bessemers vary in capacity up to 25 tons per charge in this country, and may be as large as 45 tons per charge capacity in Europe. Japanese Bessemer capacities are not definitely known, but probably approximate the range given above. An average 20 ton converter can produce about 1,200 tons of steel per day. A 20 ton converter is about 11 feet in diameter by 18 feet in length.

RECOGNITION FEATURES: Bessemer Converters are usually located either in the open hearth building, or in an adjoining one. There may be no roof across the entire top of the building over the Bessemers; when blowing, great clouds of smoke and/or a flame will be seen issuing from this gap in the roof. As stated above, however, it is reported that hoods or shields have been constructed over some Far Eastern Bessemer converters.

ELECTRIC PROCESS

Electric furnaces are steel shells resembling large cauldrons. The photograph below shows a 7-ton model:

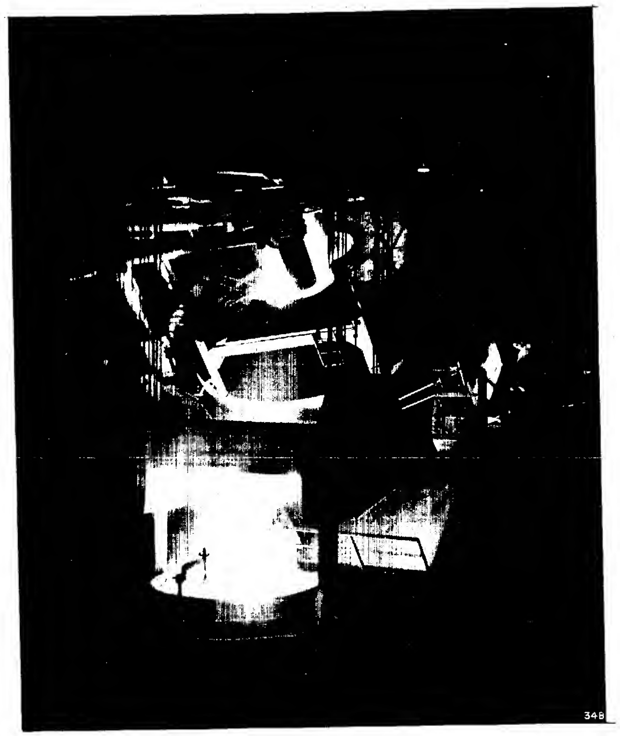

34A

Furnaces are lined with heat-resistant brick forming pan or crucible shaped interiors. These furnaces were originally used predominantly for steel refining and the making of fine alloy steels. However, the Japanese, who probably use electric furnaces to a greater extent than any other nation, may use them often for simple melting of steel scrap for steel castings or even for the remelting of pig iron for castings.

OPERATION: The furnace is charged with steel scrap, pig or molten pig, alloying metals, deoxidizers, and fluxes.

The charged material may be heated by one of two methods: (1) By an electric arc formed between the slag and three graphite or carbon electrodes which extend through the roof of the furnace towards the charge. (2) By a high frequency current induced in the body of the charge.

The weight of the charge is so regulated that the heating in the closed furnace will produce steel of the desired chemical composition within two to four hours. The undesirable elements enter the slag. When the refining process is finished, the furnace is tilted and the metal is discharged into ladles as shown below:


34B

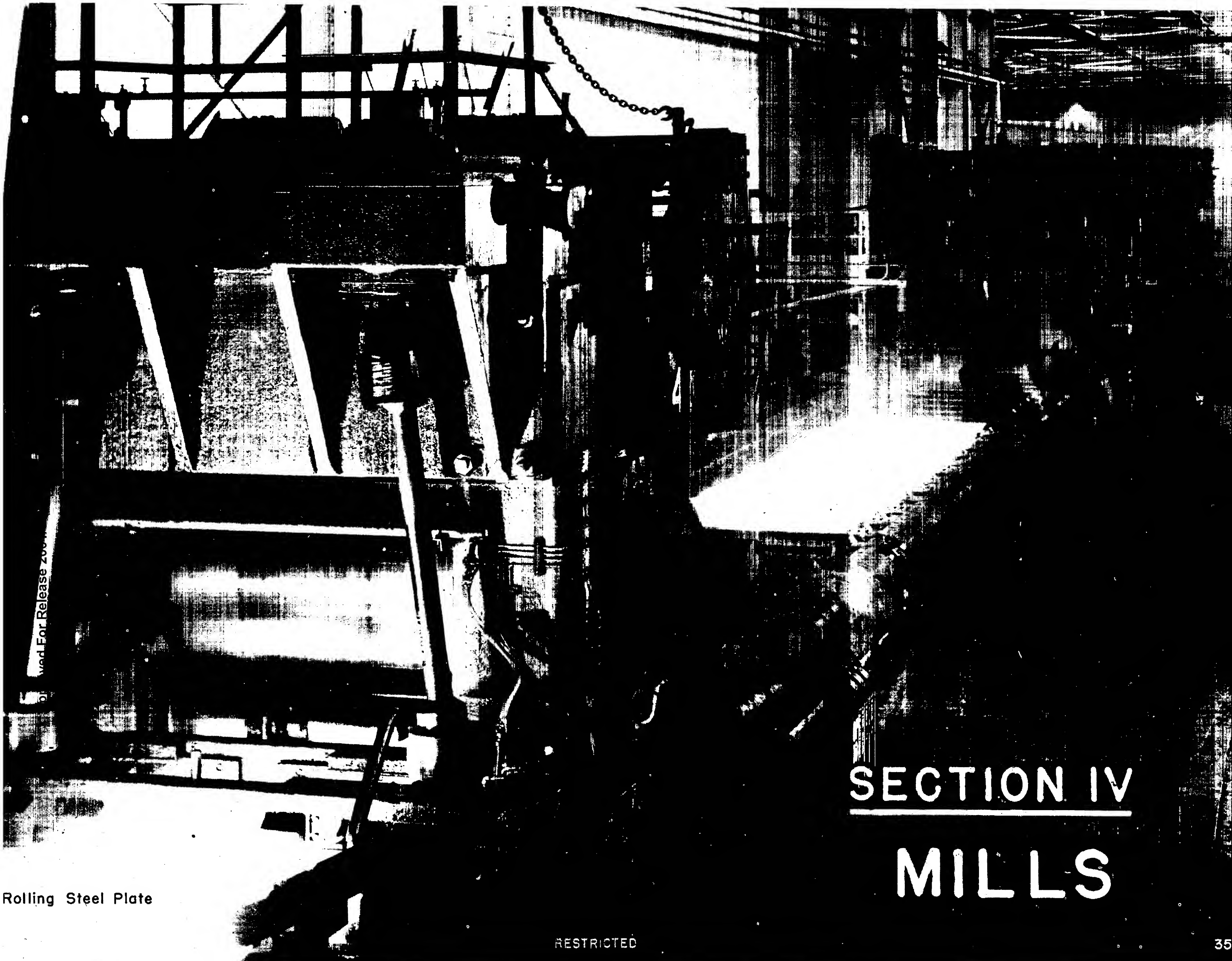
Although electric furnaces have been built with charging capacities equivalent to those of the open hearth, this type of furnace is as a rule much smaller, like the 3-ton model shown below, which is used in a foundry:


34C

Electric furnaces may consist of a single unit or be in series. They are small, and may be housed in nearly any type of building. No large quantities of reaction gases, smoke, or vapor are produced during the process and thus no stacks are required.

RECOGNITION FEATURES:

Because of their small size and the absence of stacks, it is very difficult if not impossible to recognize and identify the buildings containing electric furnaces from an aerial photograph or even from a ground photograph. The only disclosing features might be the electric power lines from the transformers which serve the furnaces; but these transformers are usually located in the same building as the furnaces and thus again may not supply any characteristic identification marks.



SECTION IV

MILLS

Rolling Steel Plate

IMPORTANCE OF PRODUCT

The rolling of finished shapes is the final step in the manufacture of steel products. Almost every war industry requires one or more of the products of steel rolling mills. The great variety of shapes needed, including plates, I-beams, channels, T-beams, angles, pipes, tubes, nails, wire, bars, rails, and spikes, indicate the number of types of mills necessary.

Among the consuming industries, ship building occupies a prominent place, since it uses nearly every type of shape turned out. The construction industry as well as the railroad, aircraft, automobile, machinery and machine tools, oil, water, gas and mining industries are also consumers of steel products.

RAW MATERIALS

The steel ingot can be considered as the raw material which is fed to the mill.

PROCESSES USED

Steel may be shaped by *rolling* in mills, by *hammering* or *pressing* in a forge, or by *casting* in a foundry. Among these methods rolling has become by far the most important, and most widely practiced of shaping processes in a steel plant. For this reason only a short discussion of forges and foundries has been included at the end of this section.

The rolling operations in a steel plant can be divided into three parts:

A. "Soaking" the ingot

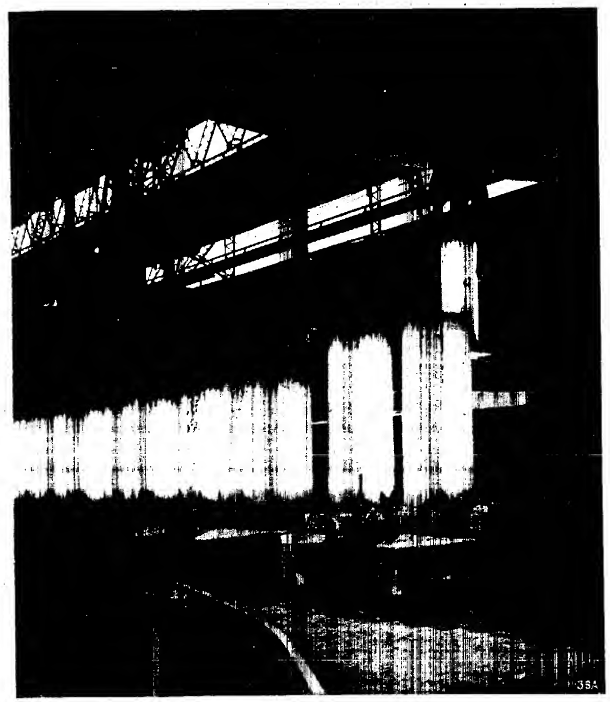
B. Rolling the ingot to form a bloom, billet, or slab

C. Rolling the bloom, billet, or slab into structural shapes.

A. SOAKING THE INGOT

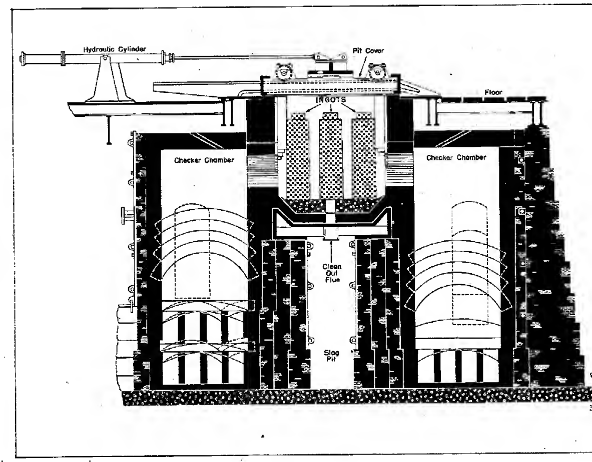
The ingot as it comes from the mold is practically in a molten state at the core, although the exterior has cooled sufficiently to permit the removal of the mold. It is much akin to a piece of chocolate candy which has a liquid center. This condition, of course, is not favorable to rolling. The ingot must be brought to a uniform consistency and heat throughout. To do this, the ingot is placed in a

SOAKING PIT. Here the interior of the ingot is permitted to cool by transmitting its heat to the exterior. At the same time, the exterior is prevented from losing its heat by the heat in the soaking pit. This eventually results in equalization of the temperature throughout the entire ingot. This process is called "soaking". The view below shows a train of ingot cars as they come from the open hearth building. The ingots are stripped of their molds and one ingot has been removed from the train and is being lowered into the pit.



The early pits were merely holes dug in the ground and lined with brick. Here the ingot was allowed to soak until the heat from the interior of the ingot was conducted to the outside and the temperature throughout became reasonably equal. This process was slow and allowed the temperature of the ingot to fall to a point where continued rolling without re-heating was impossible. It is doubtful whether this method is used even in the Far East, unless in some comparatively antiquated Chinese plant.

The present practice, and one which has been in use for considerable time, is to supply heat to the soaking pit. In this way, the temperature of the ingot is equalized more quickly and produces a soaked ingot of considerably higher temperature throughout than was possible with the old process.



Above is a cross-section drawing of a soaking pit showing its general construction. The pit cover is operated, in this case, by a hydraulic cylinder. When the pit cover is slid aside the gas and air are automatically cut off and the heated ingot may be removed. To the observer standing on the floor of the soaking pit building, only the pit cover and mechanism are visible. The pit, itself, is concealed below the floor. The diagram at top of the next column shows the complexity of construction of an improved type of soaking pit.

This pit is constructed to use producer, natural, or coke oven gas. Coal may also be used in other types.

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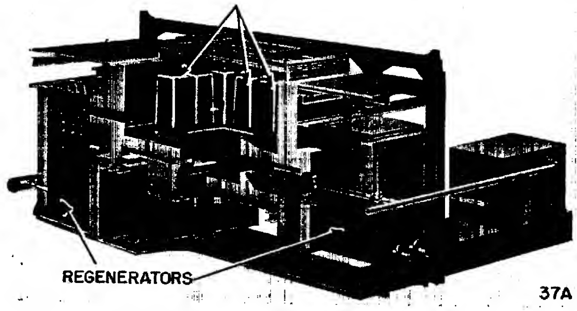
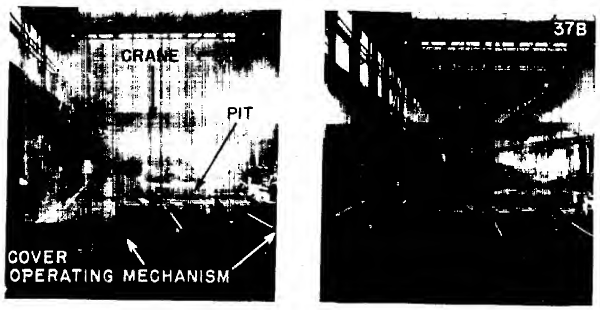
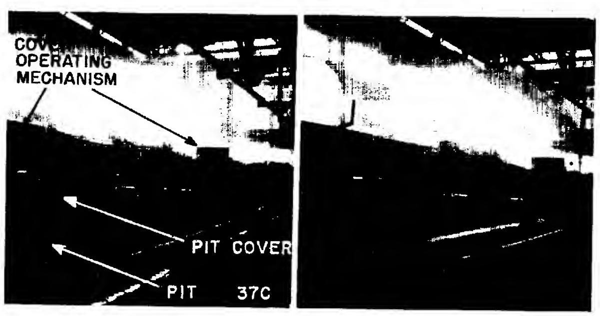
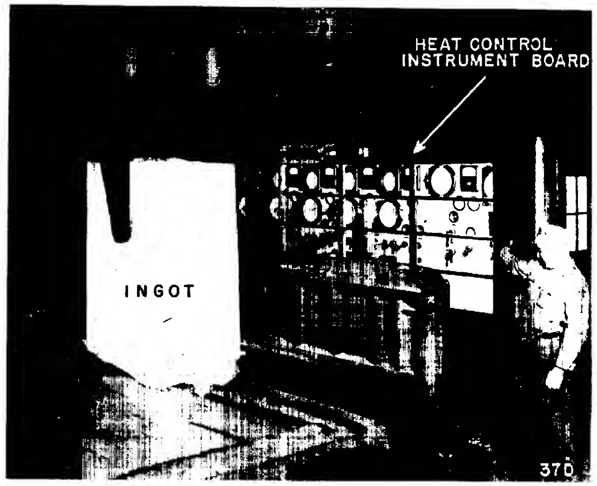


SOAKING PIT BUILDING: A general interior view of the soaking pit building is shown here, revealing rows of pits and the cover-operating mechanism:



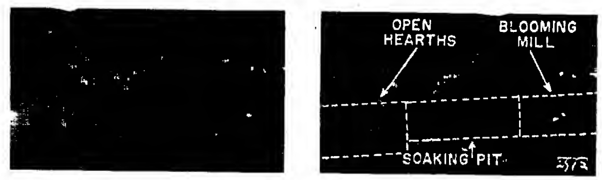
It will be noticed that the greater part of the pit is below the floor level. Much of the cover-operating equipment, as well as the heat control instrument board is vulnerable to damage, inasmuch as the roof of the building is constructed of light steel framework. Here is a close-up view of two soaking pits.

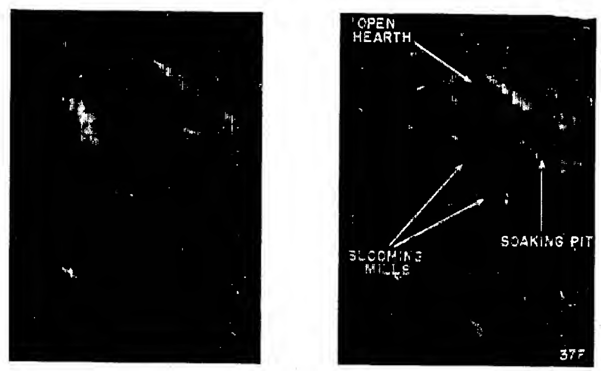




In the photo above, an ingot is shown being drawn from the soaking pit.

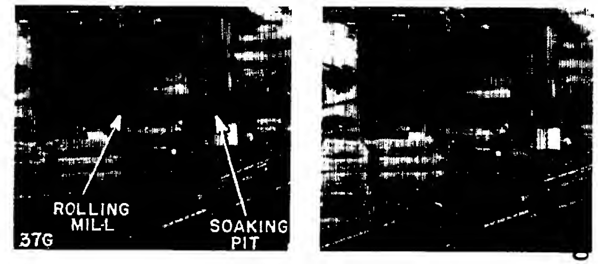
The building housing the soaking pit almost always adjoins a mill building, as shown below:





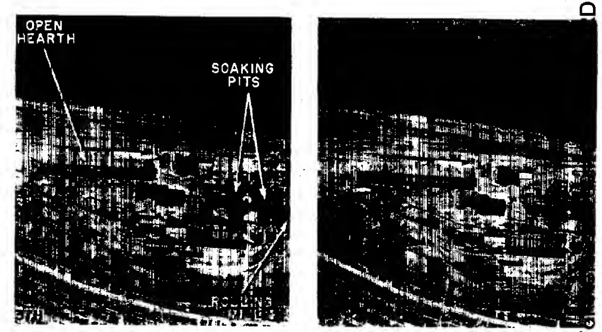
or it may be located in one part of it. In this way, the evenly heated ingots are immediately available to the mills, which are to form them into fabricated steel.

If the soaking pits are housed separately, the building will usually be at right angles to the mill buildings.



A row of small stacks which lead away the exhaust gases of the furnace are set along the side of the soaking pit building, and will aid in its recognition.

The soaking pit building should not be confused with the open hearth building which also has long rows of stacks. The two buildings are shown on the next stereogram to give a comparative view (see Fig. 37E-F) also.



The open hearth is usually a very long unattached building and much wider than the soaking pit building. The latter will almost always be attached to mill buildings, and the stacks of the soaking pit are smaller and closer together. Care may be necessary to pick out the stacks in the above stereogram.

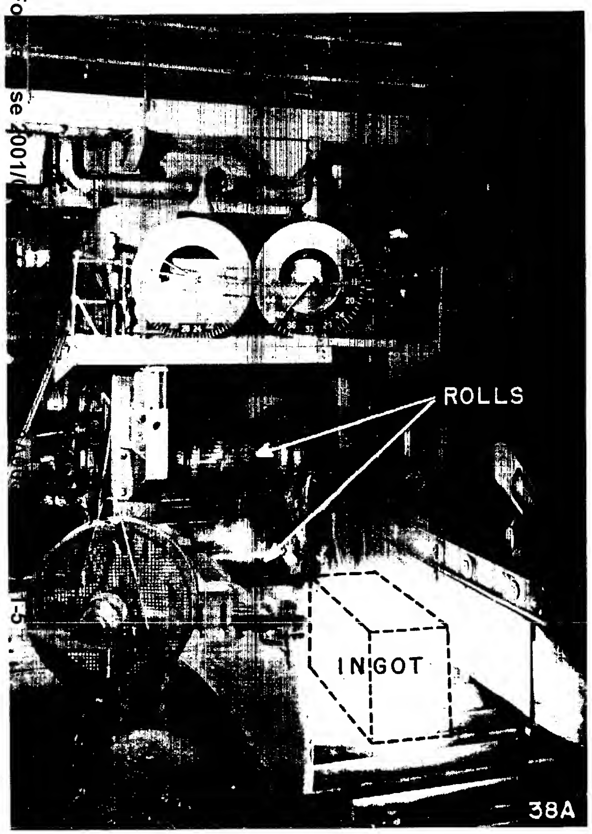
RECOGNITION FEATURES: Soaking pits are in a comparatively small building adjoining a very long one, frequently at right angles. A row of several small slender stacks is usually seen along-side the building.

Buildings housing finishing mills will also have 2 or 3 small stacks belonging to furnaces which reheat the blooms, billets, or slabs before rolling. For all practical purposes these furnaces may be regarded as secondary soaking pits.

B. ROLLING THE INGOT

After the ingot has been heated to the proper uniform temperature for rolling, it is lifted from the soaking pit, and hauled to the —

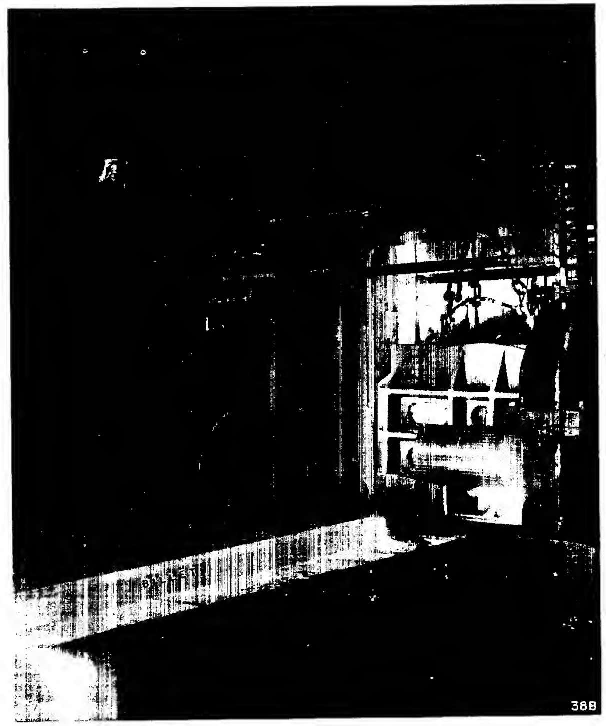
BLOOMING MILL. The rolling process consists of passing the ingot through a series of rolls. Each trip through a roll is called a "pass", the effect of each pass being to decrease the cross-section and increase the length. After several passes the ingot is reduced to a *bloom* or, if rolled sufficiently, to a *billet*. In the next view, an ingot is seen starting through the first roll.



38A

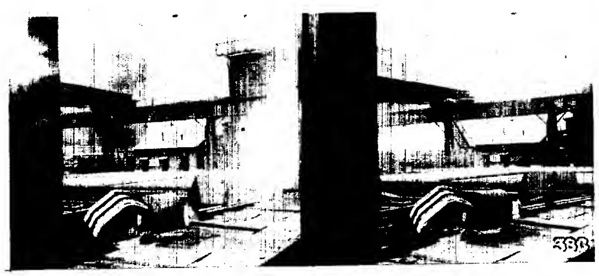
It will be formed into a bloom or billet according to the shape required for final processing.

A bloom has a cross-sectional area greater than 36 square inches, the usual form being square or rectangular in section. A billet has a cross-sectional area less than 36 square inches. Here is a billet fully formed:



38B

The next stereogram shows some billets stored out-of-doors awaiting rolling into bars, strips, or small shapes. From here, they may be sent to one of several different types of mills.



38C

In this Study the term "mill" is used either to describe the rolls inside the mill building or to indicate an entire process or special rolling operation. In colloquial usage only "mill" may be used loosely to refer to the building in which rolling is done.

There are three usual types of blooming mills, namely: continuous, reversing, and three-high. The reversing and continuous mills have pairs of rollers, one roller set above the other, and are known as *two-high* mills. Three rollers set in a vertical row is a *three-high*. Each set of two-or-three-high rolls is called a *stand of rolls*.

The *continuous mill* consists of a series of roll stands arranged in tandem so that the piece to be rolled enters the first stand and travels straight through the mill to the last stand of rolls. In such a mill, the ingots are delivered directly to the mill, the reduction to the billet being made in one continuous operation.

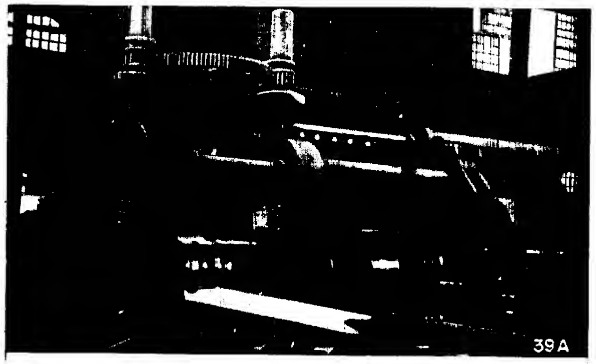
The two-high reversing, and three-high mills are not commonly used. In these types, the ingot is sent back in the opposite direction at a certain point in its travels. This permits the use of a smaller building.

SLABBING MILL: When sheet iron or steel plates are to be made, the initial product is a *slab*, whose width far exceeds its thickness. Like the blooming mill, the slabbing mill is a preliminary step in the rolling process and the slabbing will be accomplished in the same type of building. Here the operation again starts with the ingot but it is rolled into a slab shape

38D

RESTRICTED

preparatory to the final rolling of plates or other similar shapes. In the event of the destruction of the slabbing mill, slabs may be rolled on the blooming mill, but the width of the slab rolled on these mills is usually limited. Here is a slab being rolled in a blooming mill.



39A

UNIVERSAL MILLS: Slabs, billets, and blooms may all be rolled on a universal mill, which consists of a pair of ordinary plain cylindrical rolls mounted in the usual way, and at the back of these, a shorter pair of rolls mounted with their axes vertical, so as to compress the piece edgeways at the same time as the horizontal rolls compress it on the flat.

RECOGNITION FEATURES: Bloom, billet, and slab mills may be in any general type rolling mill building adjoining a soaking pit on one side and usually next to finishing mills on the other.

C. ROLLING THE BLOOM, BILLET, OR SLAB -.

The roughly shaped piece is now ready to go to the *finishing mill.* There are numerous types of finishing mills which are usually named according to the product rolled in that particular mill. The processes used in each are alike in that the billet, bloom, or slab must be heated to the proper rolling temperature, then passed through a series of rolls until the desired shape is obtained. The rolled steel may then be ready for shipment to the user, as in the case of railroad rails and structural shapes. The metal product may also be carried to another plant for further fabricating; a rod mill is an example of the latter, inasmuch as some of the rod which is rolled will be sent to the wire mill and then to the nail mill.

A great variety of milling operations may be found in a large integrated plant. Such a plant may include most of the following kinds of mills: Strip, Plate, Section, Bar, Rail, Pipe, Rod, Spike, Wire, and Nail. It is almost impossible to determine from aerial photos which product is being fabricated, and it will be well to report all mill buildings as "rolling mills" unless reliable ground information is available.

MERCHANT MILL: Some mills are not specialized for any one product. A merchant mill has small rolls, smaller than 22 inches and regularly rolls a variety of products of different cross-sectional shapes. The methods and equipment used are so typical of milling that the description of such a mill will serve as a basic description for them all.

A large merchant mill is shown in this vertical stereogram:

39B

The allignment of rolls and flow of stock within the building is outlined in the diagram below.

A crane takes the blooms or billets from storage in the billet yard and lays them on a transfer table from which they are conveyed to furnaces. The furnaces in this mill, which are fired with tar and coke-oven gas, measure 19 feet in width and have an effective hearth length of 72 feet. Here the blooms are brought to the proper temperature for rolling.

The blooms slide from the furnaces, passing over roller tables, placed in front of the furnaces, to a central table from which they are discharged onto the roller table. In No. 1 stand they are partly reduced and then pass through the continuous stands Nos. 2, 3, 4. A short table carries them to stands Nos. 5 and 6. They become smaller in cross-section and longer in length while passing through each stand. The steel continues through the various roll stands, changing its direction of flow by moving at right angles, as shown, between stands Nos. 7-8 and 9-10. From stand No. 12, the finished section passes through a flying shear, which cuts the moving steel into designated lengths. The sheared steel form goes to a run-out table which discharges to the right or left onto 255' *hot beds,* where cooling takes place. These hot beds may sometimes be placed in the open. The piece then progresses to a shear table, and finally to a cradle resting on a scale. From this point the product may be slated for direct shipment or may be stored in sheds or in the open.

The products made in this mill include differently sized and shaped bars, rods, rails, beams, and other steel structural members. The yearly production of a mill such as this would be about 300,000 net tons. The measurements included in the preceeding description of the mills refer only to this mill layout.

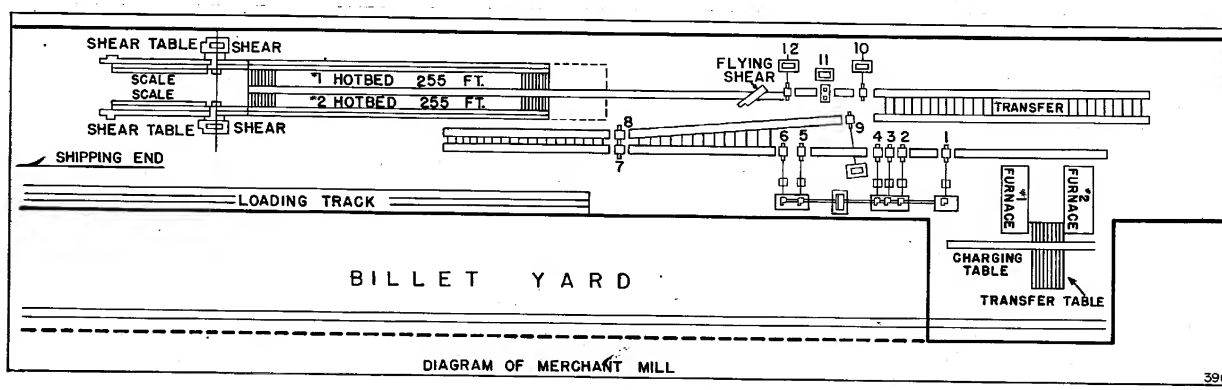
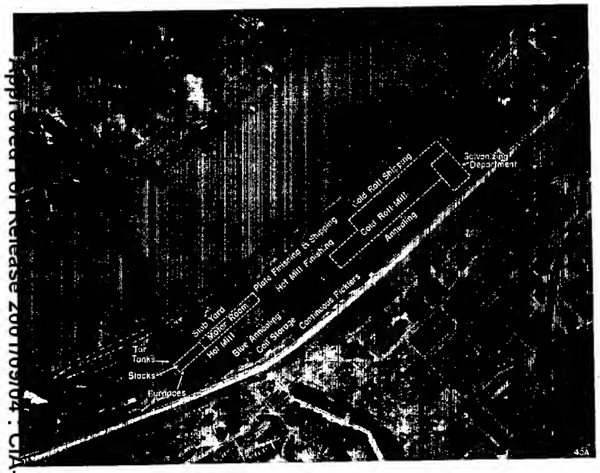


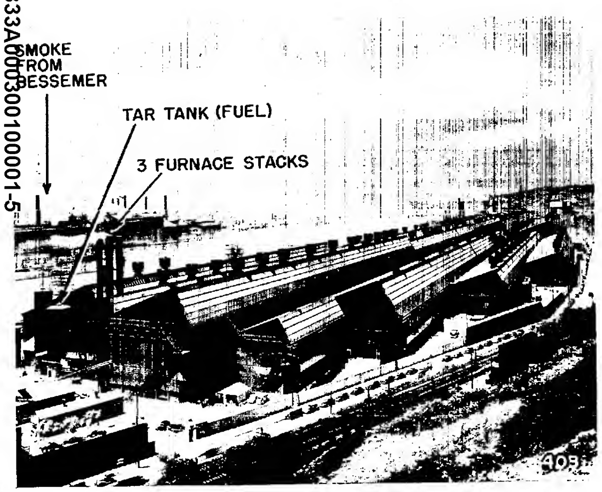
DIAGRAM OF MERCHANT MILL

39C

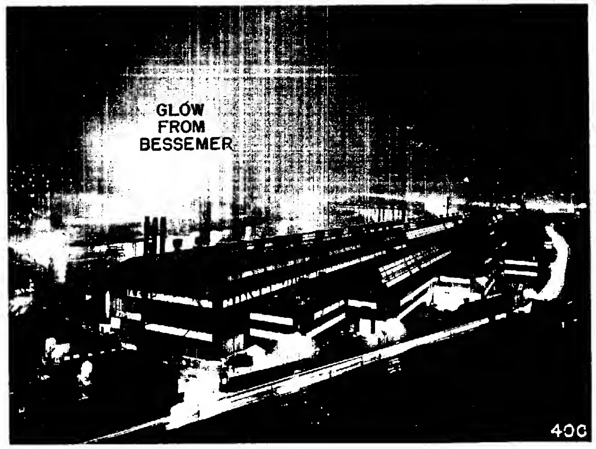
STRIP MILLS: This mill, as its name implies, is for the rolling of thin, continuous strips of steel. These strips are cut into suitable sizes for direct use or for subsequent tinning or other coating operations. Much of the product is used for stamping out various parts for automobile bodies. Both hot and cold rolling methods are used in the strip mill.



The above aerial photograph shows a large domestic hot and cold strip mill. This is how it looks from the ground:

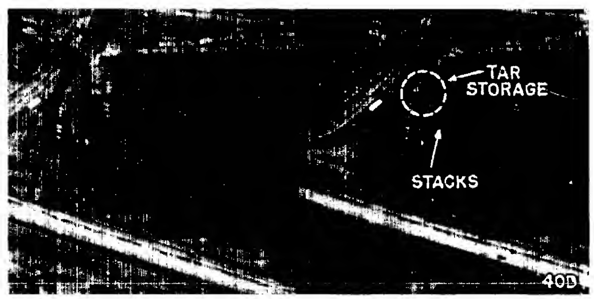


and during night operation from the same spot.



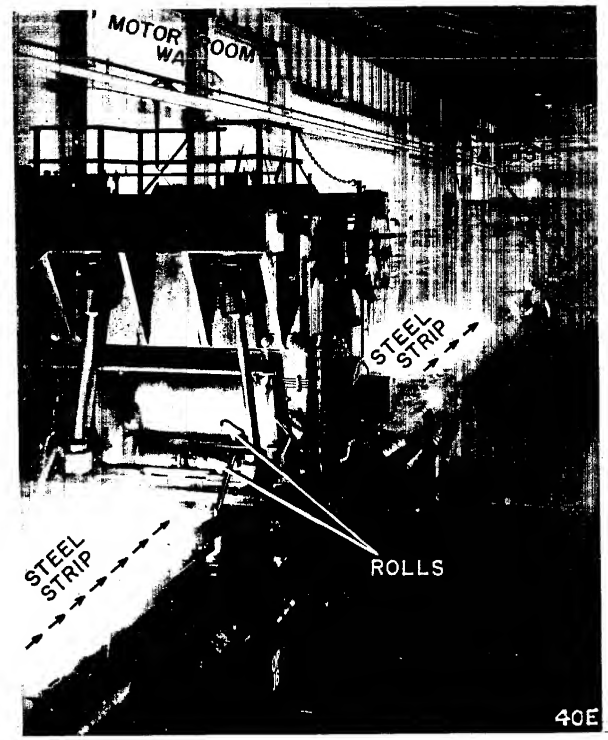
The glow from the Bessemer converter lights up the sky in the distance.

In the *hot method* slabs to be rolled into strips in this mill are first placed in a furnace and heated to rolling temperatures. The stacks of three furnaces and tar storage tanks appear in the stereogram below:

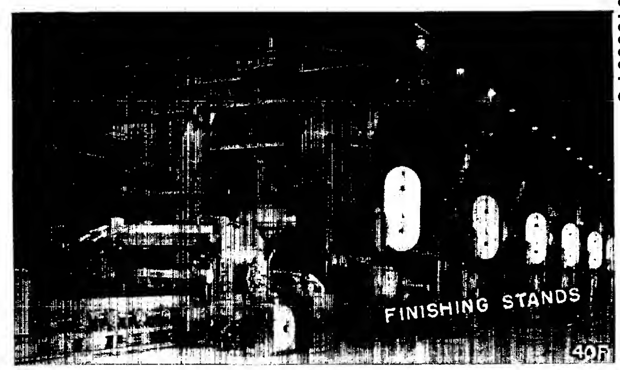


A domestic type of furnace has a rating of 50 gross tons per hour of cold slabs 6" in thickness for a hearth 79' x 18'. This furnace is fired with both coke-oven gas and tar.

Slabs are discharged from the furnace at temperatures of 2100-2300 degrees Farenheit and are conveyed onto the mill approach table where they will start the continuous rolling operations.



Here the strip is seen in the middle of its journey through the mill. The strip will pass through a dozen or more sets of rollers and emerge from the final stand at a speed of from 1700 to 2000 feet per minute. The finishing stands are placed close together and are of massive steel construction.



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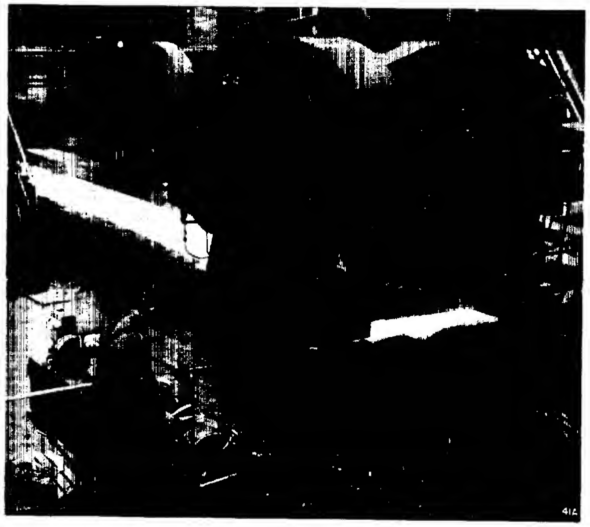
The following view shows the tail end of a hot strip being cropped off by the shears, after which it will go to the finishing rolls just described.

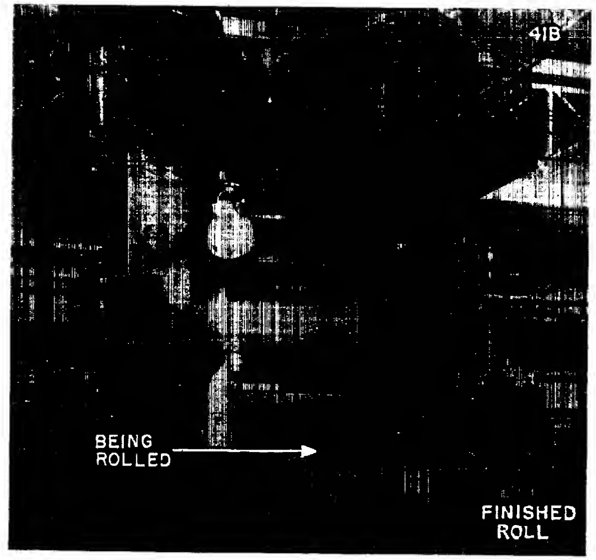


The strip travels on beyond the last stand to the coilers from which the coiled strip is conveyed to storage. Coils that are to be cold-reduced are treated in special acid solutions and are then sent to the cold rolling mill to be further processed.

The hot mill *motor room* contains the electric power drivers for the continuous hot mill. The motors are located in a large room adjoining the rolls and separated by a wall which is shown in 40E. The positions of the motor room and the furnaces are indicated in photograph 40A. They are vitally important parts in this type of mill. Without the furnaces or the power to drive the hot mill, operation of both the cold and hot mills will be held up. These motors are large and would be hard to replace, especially in wartime.

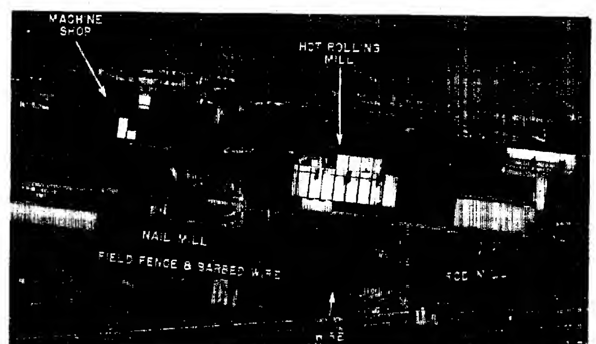
The *cold method* is used after the acid treating process mentioned above. The strip is run through breakdown rolls where it is reduced 30 to 50 percent in cross-section and again coiled.

The photograph at the top of the next column shows a completed roll in the foreground and another on the machine, being rolled. The metal is hardened by



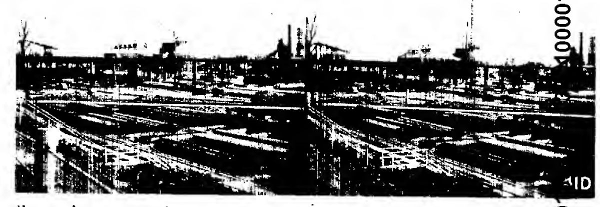
the cold rolling operation and must now be *annealed.* This is usually done by packing the coils and covering them with an airtight steel hood. The base and hood, with contents, are pushed into a furnace and annealed for about twelve hours at 1450° F. The hood with its contents is then removed from the furnace and cooled.

MISCELLANEOUS MILLS: The group of mills discussed below are some that will be found at most steel plants. They may be found in separate buildings or as parts of a building which includes a number of mills rolling different products. The building shown below is of a type in which many assorted small items such as nails, wire, barbed wire, fencing, etc., could be produced.



In addition, this building could house many of the mills mentioned below.

The *rail mill,* which turns out finished railroad rails, is similar in process to other rolling mills, and the building in which the work is done will probably not be identifiable from aerial photography. The storage yard for rails, however, is likely to be in the open, and may lead to the identification of the mill as a rail mill on good photographic coverage.



Here is a vertical view of the same area:

The *plate mill* is very important for war production. Armor and other plates for the shipbuilding industry probably consume most of its output. A strip mill may also be used for rolling plates. The storage yard may offer a clue to the location of this mill.

The *section mill* rolls structural shapes, channels, "I" beams, angles, etc., for the construction industry and numerous other industries dependent on this form of steel. The mill building in which these members are rolled would not differ from any of the others. The storage of this type of steel may again be in the open but may be confused with rail storage in photography of indifferent quality.

The *wire mill* uses rod made in the rod mill for the manufacture of wire. In the wire-drawing operations the rod is pulled through a die; this is a cold operation.

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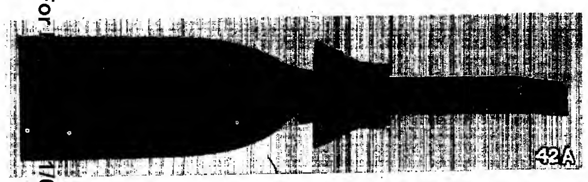
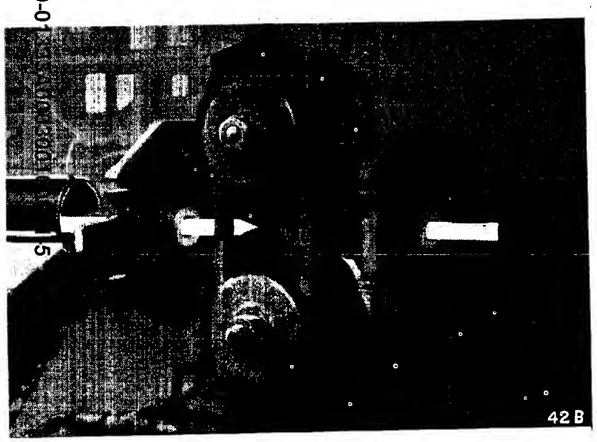
After being drawn through the die, the wire is coiled for shipping and in most cases stored under cover. The mill building for the manufacture of wire would not differ from other ordinary mill buildings.

Pipe and *tube mills* produce the finished product by a method entirely foreign to the other mills. The pipe and tube is made from *skelp*, which is a strip of steel of the proper cross-section to give the diameter and wall thickness desired. This skelp is hot-rolled from blooms or slabs, and then heated in furnaces which bring it to a welding temperature. The heated strips are then drawn, while hot, through suitable dies, which bend the skelp into a cylindrical form, like this:


42A

The edges are then pressed together by means of deep-grooved rolls which perform the welding operation. The welded pipe is passed over a mandrel which fixes the internal diameter, and is then passed through additional sets of rolls among which are the sizing rolls which fix the external diameter. The following photograph illustrates sizing rolls for small diameter pipe.


42B

Pipe and *tube mill* buildings also cannot be distinguished from any other mill buildings. Open storage of pipe and tubing may be confused with rails and beams.

Bar, rod, and *spike mills* may also be present at a large steel plant but the aerial photographs of those would offer very few, if any, clues to aid in the identification.

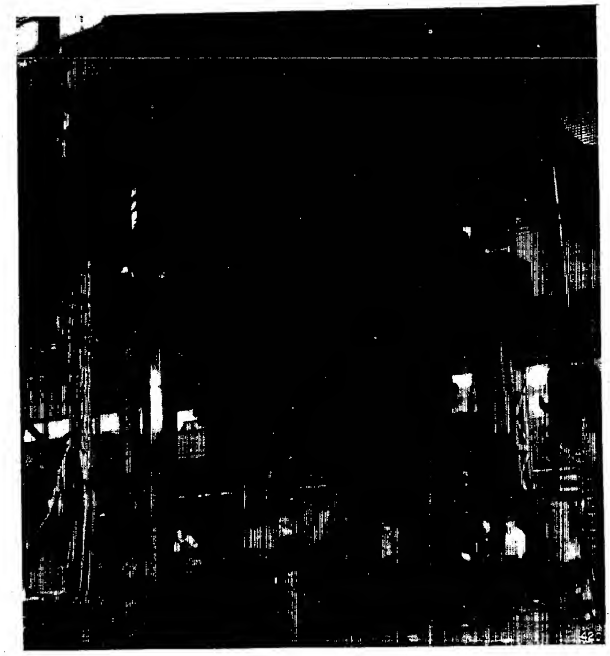
In a modern *nail mill* one will find from 150 to 300 separate machines, each of which is capable of turning out from 150 to 350 finished nails per minute. In front of each machine is a reel upon which a coil of drawn wire is placed. One end of the wire is led into the machine driven by an electric motor. A stream of finished wire nails begins to pour out of the opposite side of the machine. Nails are packed in small kegs which may be stacked under cover or in the open. Nail mills also are indistinguishable from other mills.

MILL BUILDINGS: In general, a mill building is of steel frame construction with light exterior walls and roof of corrugated sheet metal or asbestos. The walls are constructed to allow as much ventilation and light as possible and the roof usually has large monitors extending the full length of the building. The height of a typical mill building is from 30 to 50 feet with a width of 50 to 80 feet being average.

The lower part of the structural frame will be heavy and rigidly braced in order to carry the overhead travelling cranes used to handle the metal and move the equipment. The effect of blast on the building would probably be to collapse the walls, windows, and roof without greatly damaging the steel frame.

FORGES AND FOUNDRIES: Certain steel and iron products cannot be manufactured in the rolling mill, but must be forged or cast. Crankshafts and hammerheads are examples of shapes which can only be formed under the hammer or press, since they require the strength, ductility, and soundness imparted by forging, and are too intricate to be rolled. Large gears, locomotive frames, engine beds, and propellers, on the other hand, are examples of the many shapes best produced by casting.

In *forges*, the hot iron or steel is shaped by means of a hammer or press. Equipment used includes power-driven drop hammers, hot and cold presses, and sometimes anvils and sledge hammers. The forges themselves are the furnaces in which the metal is heated preparatory to being worked. Forges are hooded, with stacks protruding from the hoods, which may be either above or below roof level. Soaking pits for blooms or billets may be seen in the forge building.



In the *foundry* molten steel and iron are made into castings. The steel is used direct from Bessemer, open hearth, or electric furnaces, while the iron pigs may be melted in cupola furnaces in the foundry building. The cupola furnace is essentially a small blast furnace using cold air blast. The waste gases escape into the air through a stack or large vent, which may be seen in the foundry roof.

The preparation of the molds, heat treatment, and finishing may take place in separate shops, which may or may not be under the same roof. The interpreter will frequently find molds and sand piles lying in the open near a foundry. A machine shop is commonly offset from the main building.

Forge and foundry buildings are best located by their position relative to other iron and steel units; they are usually taller than other buildings in a steel plant, and are generally broader in proportion to their length than open-hearth buildings. The roof will usually be of gable or monitor type.

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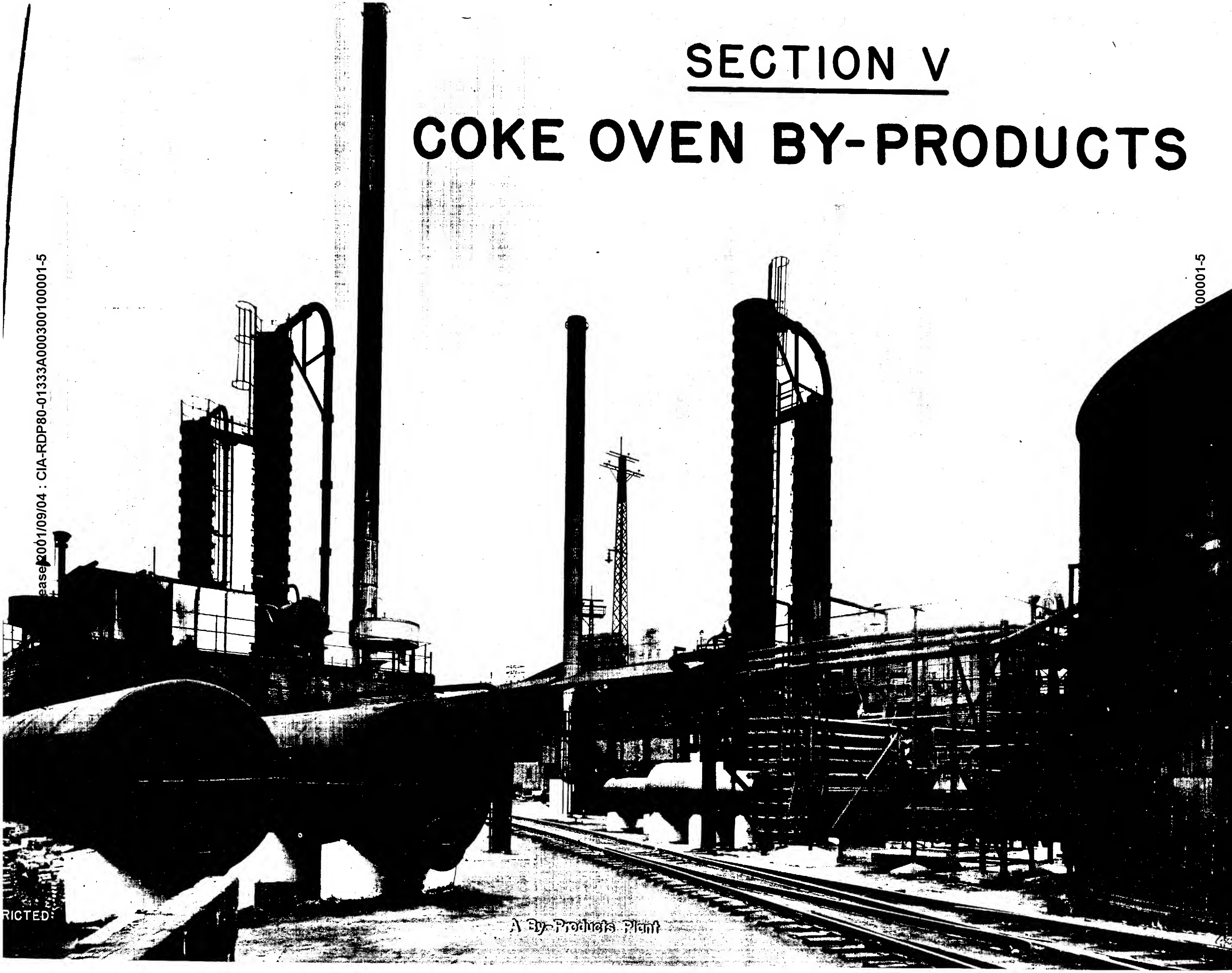
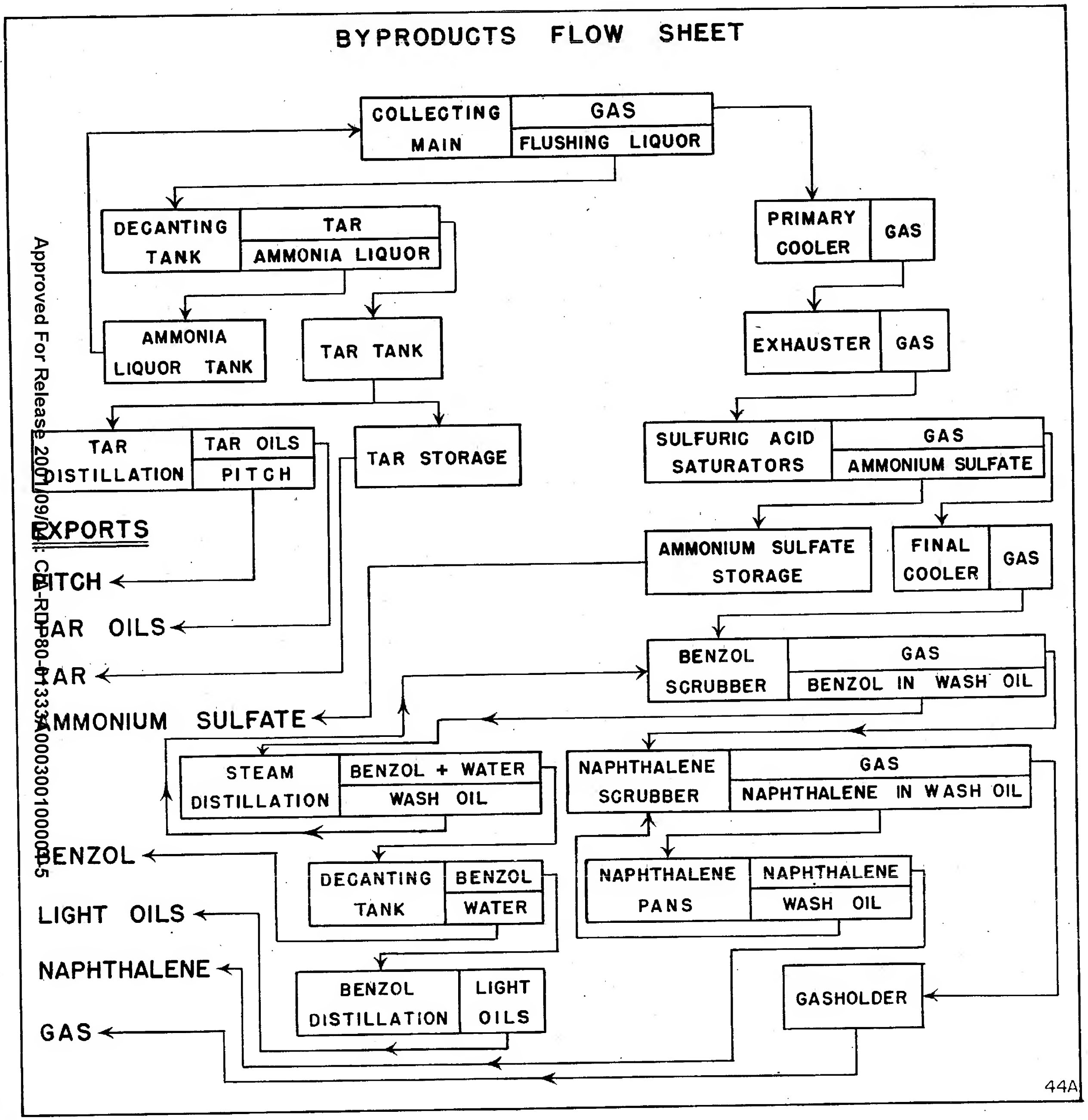
SECTION V

COKE OVEN BY-PRODUCTS

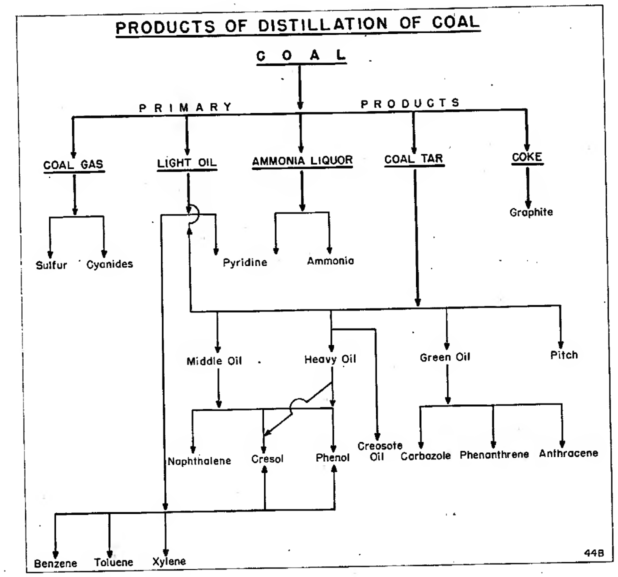


A By-Products Plant



IMPORTANCE OF PRODUCT

The volatile materials distilled from the coal in the coke ovens are valuable and important. They consist of coal gas, coal tar, ammonia, and light oil. These, together with the solid residue, coke, comprise the five primary products of the destructive distillation of coal, as shown in the following chart:



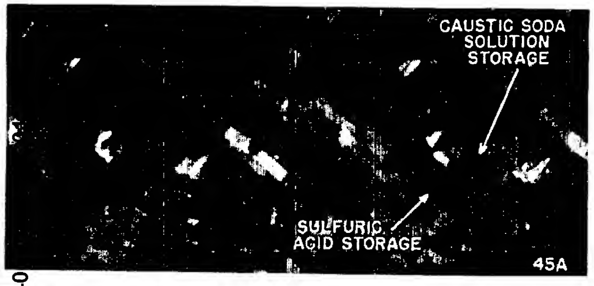
Countless products are ultimately derived from them, including such important wartime materials as explosives, drugs, dyestuffs, fertilizers, insulators, plastics, and nitric acid. Just a few of the principal compounds extracted from these five primary products are shown in the chart.

Byproduct plants directly associated with coke ovens vary in operational practice and in the degree to which they carry out the separation of the constituents of coal gas and tar. In general, however, the byproduct plant merely supplies the raw materials from which specializing manufacturers produce such diverse and well known products as aspirin, picric acid, T.N.T., carbolic acid, vanillin and aniline.

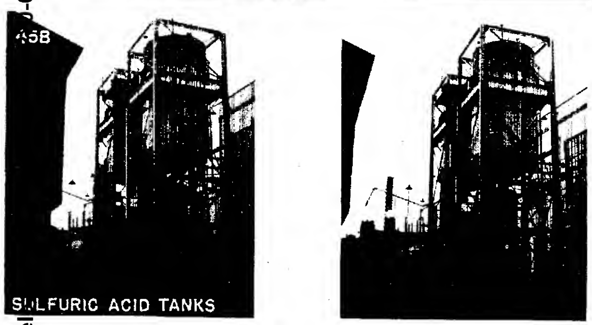
RESTRICTED

RAW MATERIALS

The *gas* and *tar* as they leave the coke-oven ascension pipes may be regarded as the principal raw materials. *Sulfuric acid* and *caustic alkali* and-or *lime* are the only materials commonly brought in from outside. Apart from small stocks of these, there is no raw material storage in a byproduct plant.



45A

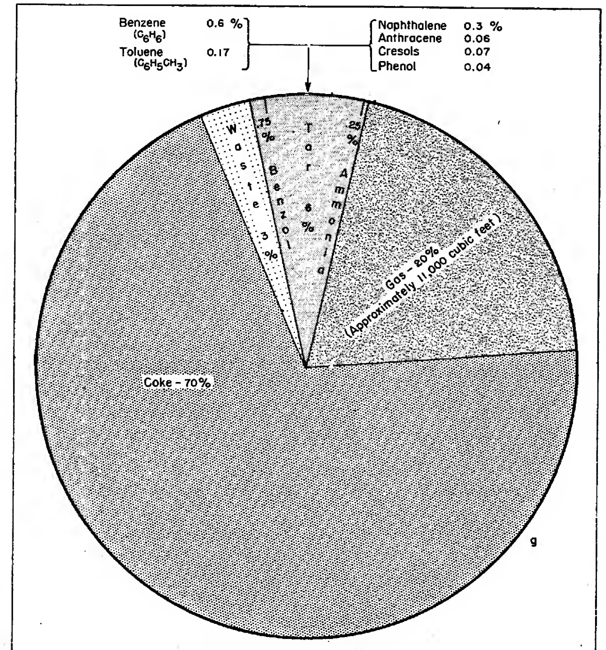


45B
SULFURIC ACID TANKS

Water, steam and *electricity* are essential utilities, which must be continuously supplied if the byproduct plant is to function. Usually coke-oven plants operate their own pumping stations and details of steam and electricity supply are given in the "Utilities" section of this Study.

PROCESSES USED

The byproduct process separates from gases and tars the valuable substances which are contained therein. This is accomplished by separatory methods such as decantation, scrubbing and distillation. The diagram at the top of the next column gives the approximate relationship between the percentages of by-products, coke and gas.



AVERAGE PRODUCTS OF CARBONIZATION OF ONE TON OF COAL
(Percentage by weight of dry coal charged)

45C

It will be noticed that the total quantity of by-products is small in comparison with that of the gas and coke.

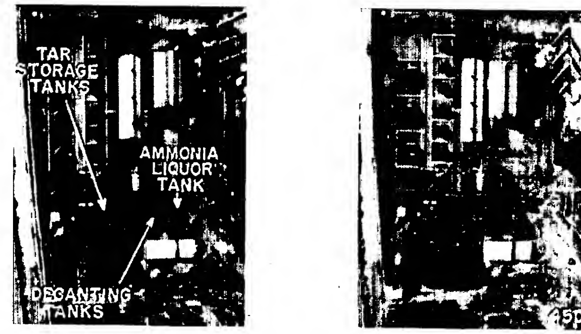
It will be recalled how the hot tarry gas from the individual coke ovens was gathered by the collecting main and cooled by the ammonia liquor spray. The ammonia also acted as a flushing agent carrying away tar fractions. This is really the beginning of the by-product process.

Inasmuch as there are both gases and liquids in this main, they must be drawn off separately. (1) The *liquids* go to decanting tanks; (2) The *gases* go to the primary coolers.

A. THE LIQUIDS

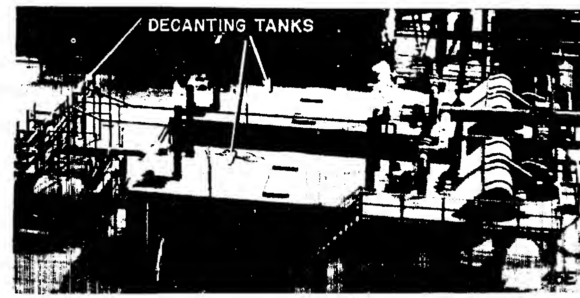
The liquids which were separated from the gases at the collecting main are piped to -

DECANTING TANKS: Here the liquids separate into an upper layer of ammonia liquor and a lower heavier layer of tar. Decanting tanks may be cylindrical:

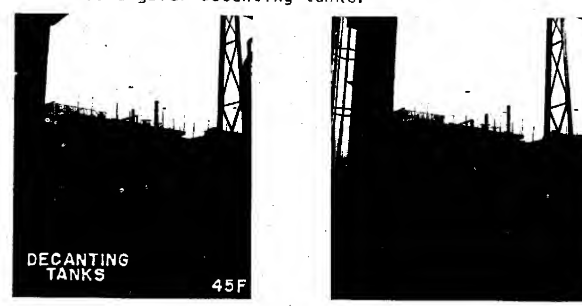


45D

Or rectangular:



More rectangular decanting tanks:



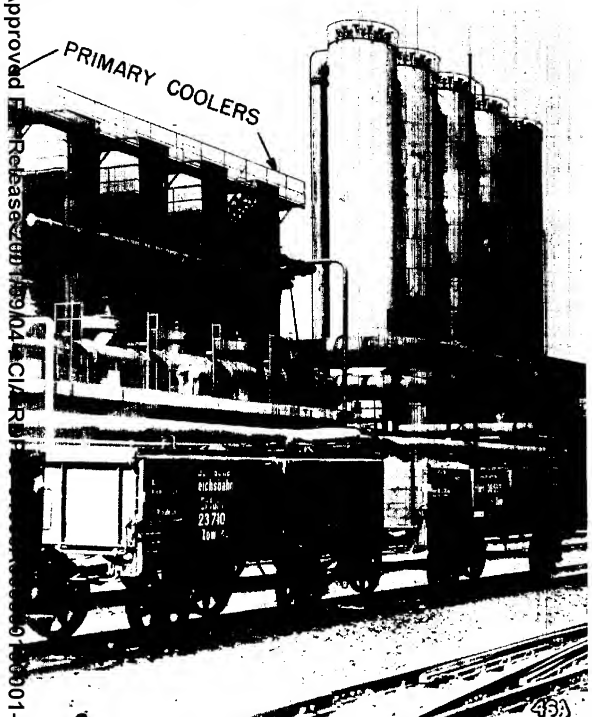
45F

Storage tanks for tar and the ammonia liquor are generally close by, as shown in photo 45D. The capacity of the tar tanks will be greater than that of the ammonia liquor tanks, because most of the ammonia liquor is recycled through the flushing sprays in the collecting main.

B. THE GASES -

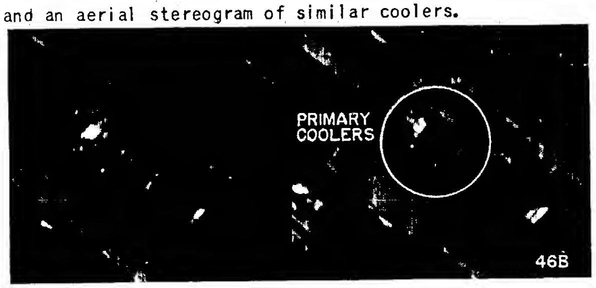
The gases leaving the collecting main are too hot and contain too much tar for them to be handled by the exhausters. The gases must first be cooled. This is done in the -

PRIMARY COOLERS: which are rectangular or cylindrical hurdle-packed towers. Here is a ground shot of rectangular primary coolers.



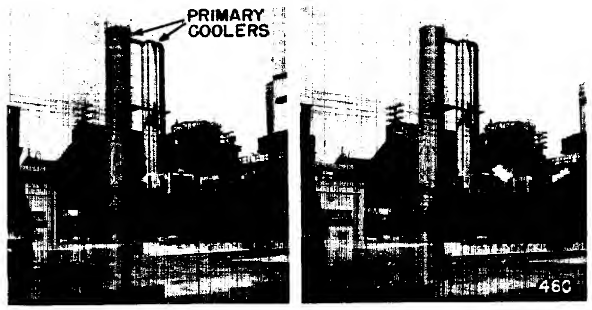
46A

and an aerial stereogram of similar coolers.



46B

Cylindrical cooling towers are shown below:

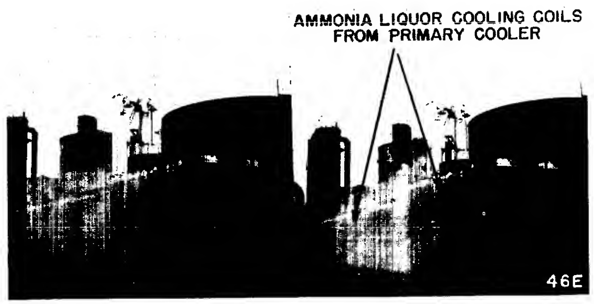


46C

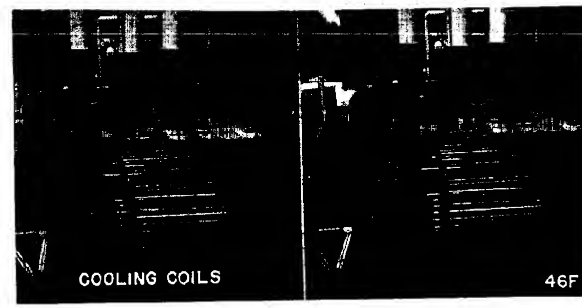
The gas is carried directly from the collecting main to the coolers by a *cross-over* or *suction main,* which will aid in recognizing the coolers.

46D

The gases enter at the bottom of the cooling tower and ascend against a descending stream of ammonia liquor. The liquor is drawn off at the base of the tower and passed through *water-cooled coils* such as these:



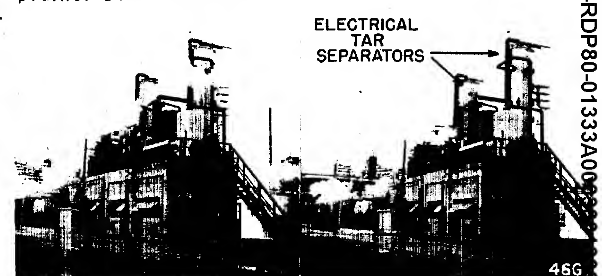
46E



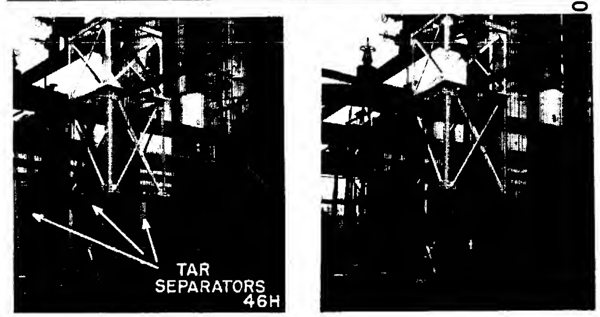
46F

The liquor is then recycled to the primary cooling tower for the cooling of the new gases. This is the second of the two separate ammonia liquor cycles. The water used in cooling the ammonia liquor is itself cooled by any of the cooling systems described in Industrial Study No. 2, pp. 30 and 31.

The ammonia liquor sprayed to flush out the tar in the collecting main is not completely effective. Some of the tar remains in the gas. This tar is removed by mechanical or electrical *tar separators* shown below. These tar separators may occur at a later phase of the process, or may be omitted in certain cases, as explained under "Exhausters".



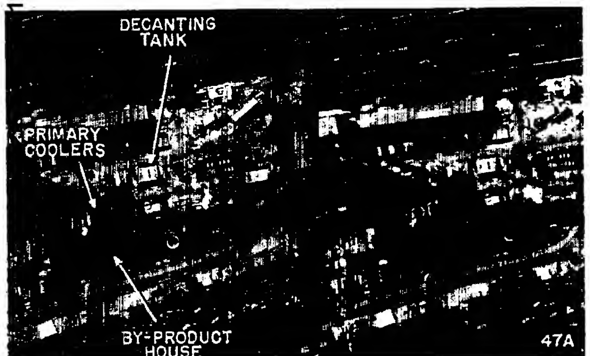
46G



46H

The cooled gases are now ready to be sent to the -

BYPRODUCT BUILDING - The equipment housed here controls the circulatory systems in all phases of by-products recovery. This building is the most vital part of the byproduct plant. The location of the byproduct building will vary in relation to the other installations on the plant site. In the interpretation of aerial photographs, it is a fairly safe rule to regard as the byproduct house the first large building to which the gas passes after it leaves the primary coolers.



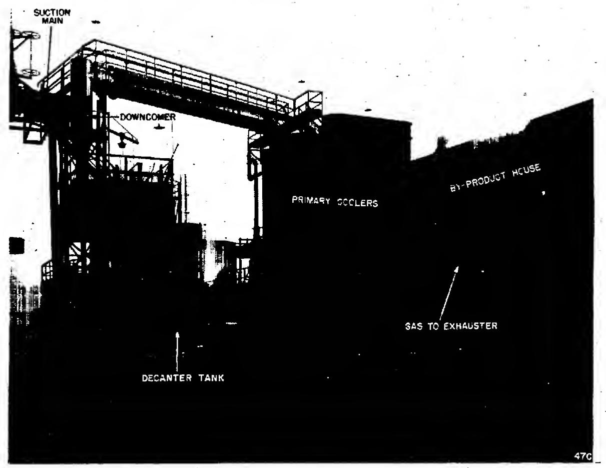
47A

The gas may encounter other smaller installations between the primary coolers and byproduct building, as shown below:

47B

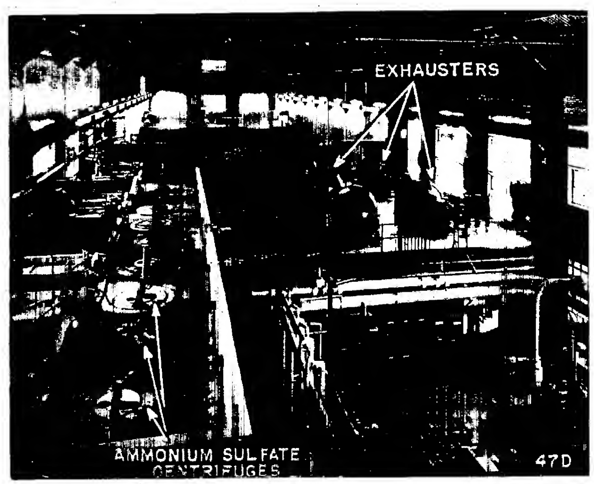
The photograph at the top of the next column shows a typical layout of equipment from the coke ovens to the byproduct house. Upon entering the byproduct building, the gases go through the -

EXHAUSTERS: Up to this point the gases have been under suction created by exhausters (described under Coke, page 12). Centrifugal exhausters may serve as tar separators also.



47C

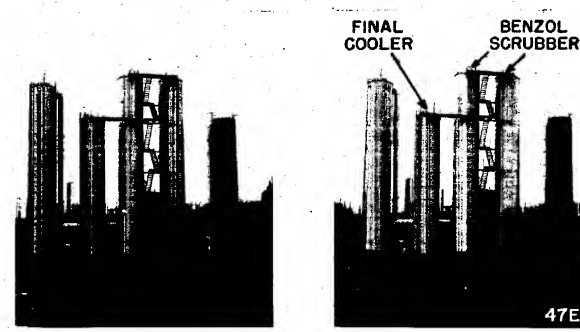
The following photograph shows five exhausters inside the byproduct house;



47D

The gases then pass on under pressure through sulfuric acid saturators, mentioned below under Ammonia Recovery, and proceed to the *final coolers*. These are tall slender cylindrical towers. Upon leaving the final coolers, the gases enter the -

BENZOL TOWERS OR SCRUBBERS: These are also tall cylinders, two of which are pictured in Fig. 48E.



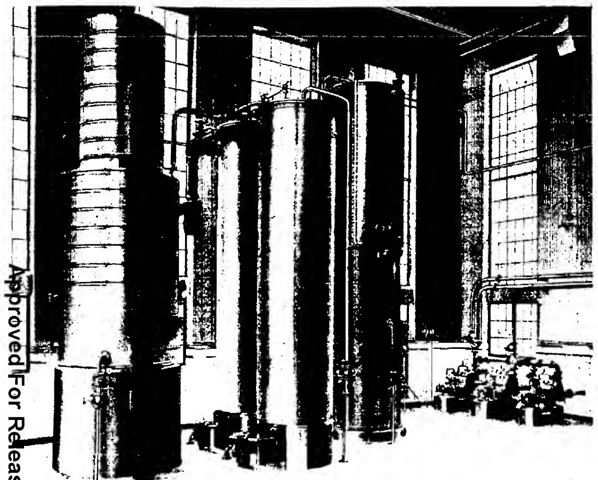
47E

Here are the final coolers and benzol towers in vertical view:

47F

In the benzol towers benzol is removed from the gas by being dissolved in wash oil. The solution is taken off at the bottom of the tower. The term "benzol" is used in this Study to describe the mixture of light oils (volatile hydrocarbons) condensable from coke-oven gas. The de-benzolized gas, which will eventually be used as fuel, leaves from the top of the tower, while the wash oil is pumped to the -

BENZOL BUILDING: The mixture of light oils known as benzol must be extracted from the wash oil which dissolved it out of the gas stream in the benzol scrubbers. This is done in the benzol building, by steam distillation, which gives a condensate of benzol and water. The benzol is separated by decantation from water with which it will not mix. The illustration at the top of the first column of the next page shows the apparatus used. The view at the top of column "b" on the next page shows a benzol building and a fractioning column for extraction of a pure hydrocarbon.



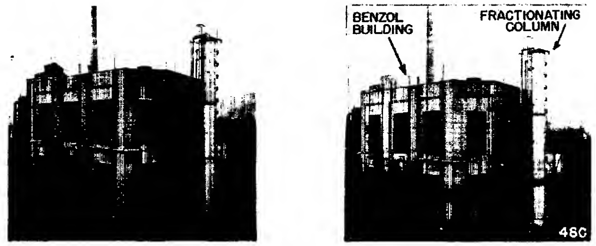
WASH OIL DISTILLATION 48A

The benzol thus obtained is commonly sold in the crude state. In some plants, however, hydrocarbons of a high degree of purity, such as benzene and toluene, are obtained by fractional distillation. The next photograph shows fractionating columns inside the benzol building.

INTERIOR OF BENZOL BUILDING

48B

An outdoor fractionating column is seen in the stereogram of the benzol building below:

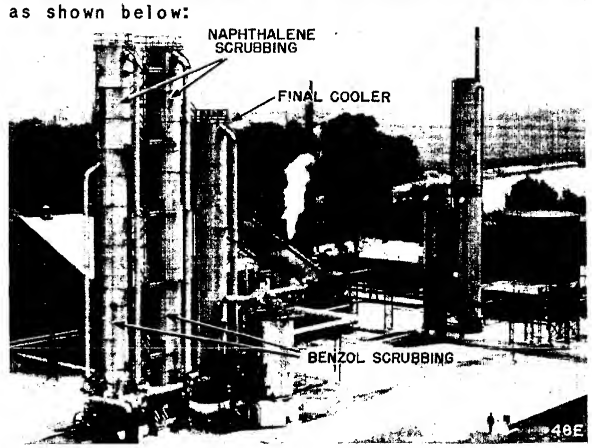


48C

The process used is similar to the fractional distillation in the oil refining process described in Photo Industrial Study No. 2, pages 28 and 29. The fractionating column used in a byproduct plant is smaller. Here is a group of fractionating columns as seen from the air:

48D

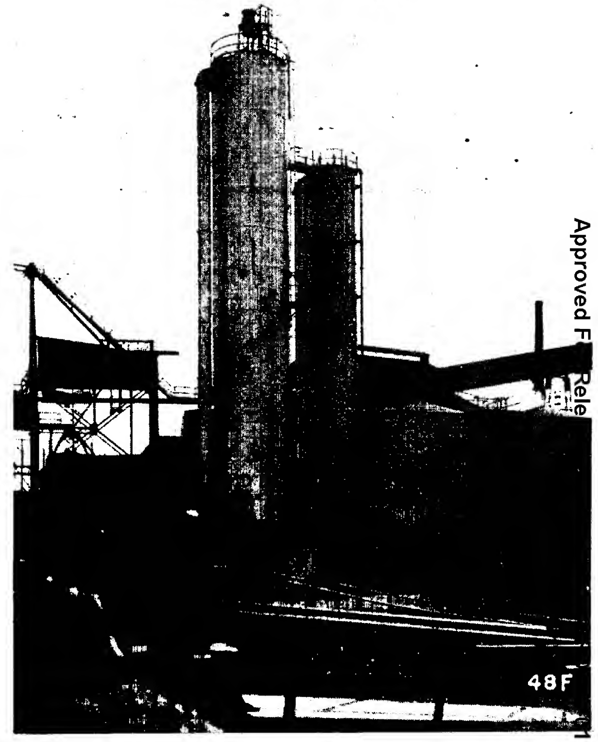
Sometimes an extension at the top of the tower, as shown below:



48E

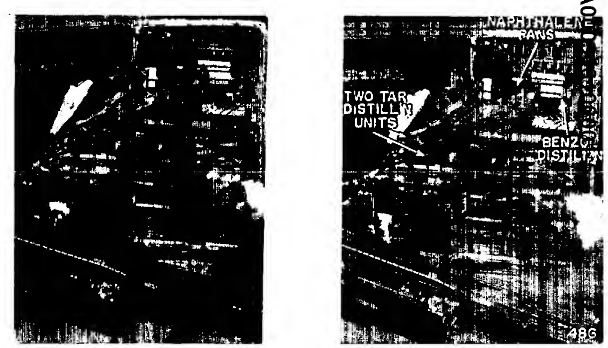
Naphthalene, used in making dyes, is washed out of the gas in these extensions. More often there are separate washers for naphthalene, as shown in photograph 48F. They resemble benzol scrubbers, but may be distinguished because they follow the benzol towers in the gas flow. The naphthalene is washed out of the gas with oil, and is recovered from solution in oil by crystallization in

NAPHTHALENE PLANT



48F

open pans. Some naphthalene pans are shown below:

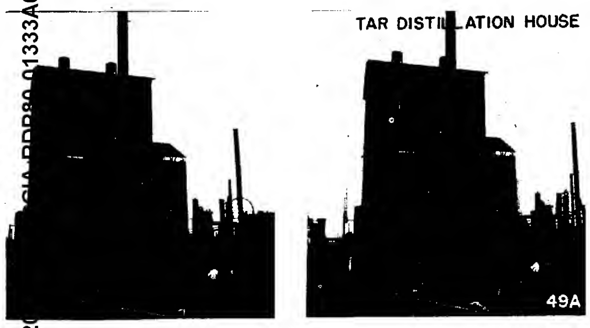


48G

So far, the recovery processes have been considered as taking place from the gas stream alone. In actuality, most substances contained in the gas are also present in the liquor, in quantities of varying im-

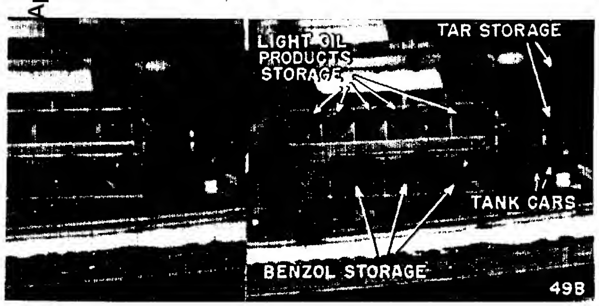
portance. Benzol and naphthalene, for example, while mainly extracted from the gas, may also be extracted from tar, in those plants which are equipped for tar distillation. Recovery of tar and ammonia from both gas and liquid will be discussed below.

TAR RECOVERY AND DISTILLATION: The bulk of the tar is recovered in the decanting tank, but additional quantities are gathered from the primary coolers, tar extractors and centrifugal exhausters. The initial distillation of tar gives crude mixtures such as creosote oil. From these oils pure substances such as phenol, naphthalene, anthracene and cresol may sometimes be extracted by further distillation. Distillation is not carried to this extent in many steel mill coke plants, which usually distil the tar to not more than three broad fractions.



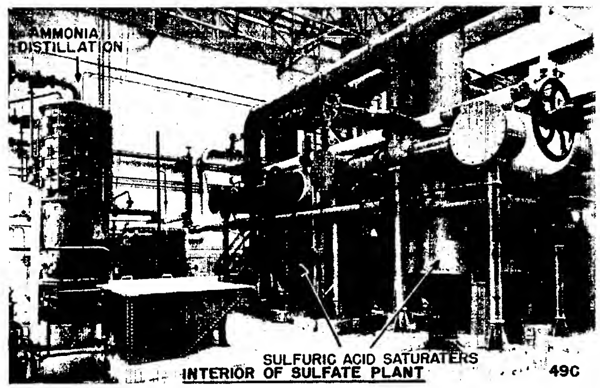
49A

In most cases the tar will be sent for processing to other plants, where it will be distilled with greater precision. The residue from tar distillation is pitch, which may be used, among other things, for fuel or as a binder in the manufacture of carbon electrodes for the aluminum industry. This will be fully covered in the Photo Industrial Study on "Aluminum". Tar storage tanks, and tank cars equipped with steam coils for tar transit are shown below:



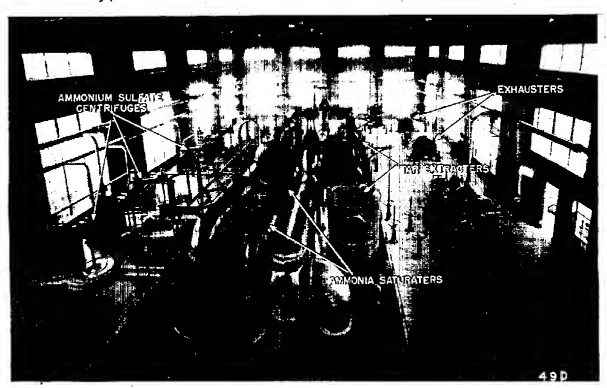
49B

AMMONIA RECOVERY: It will be recalled that ammonia liquor circulates in both the collecting main and primary coolers. In both places water condenses from the gas and dissolves a small percentage of the ammonia present in the gas. Thus there is an accumulation of excess ammonia liquor in the collecting main and primary cooler circuits. Much of the ammonia has combined with soluble organic acids from the coal to form salts. Before the ammonia can be recovered it must be freed from the acids with caustic soda or lime and then distilled in the apparatus shown in the following photograph.



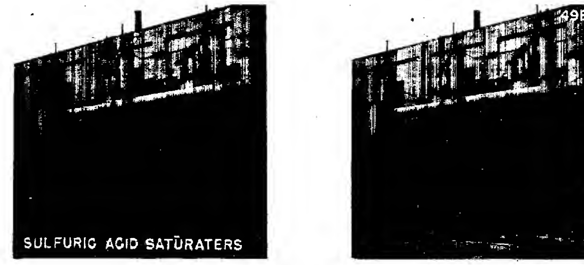
INTERIOR OF SULFATE PLANT
49C

A much greater quantity of ammonia is carried in the gas stream out of the collecting main and through the primary cooler to the byproduct house, where the ammonia is absorbed in *sulfuric acid saturators*. This produces ammonium sulfate These saturators are sometimes housed in the byproduct building itself. The equipment used is shown in this view of the interior of the byproduct house:



49D

Saturators are sometimes placed in the open as seen in the next photo.

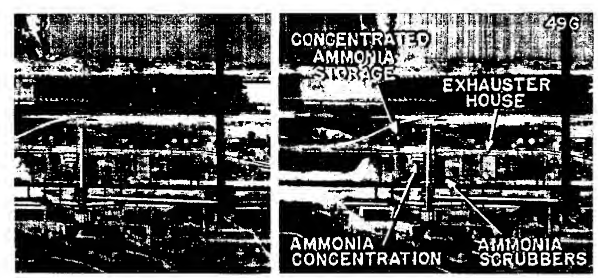


49E

Although the whole ammonia plant is often in a part of the byproduct building, it may be housed separately. Ammonium sulfate may be stored in the byproduct building, or separately, as shown below:

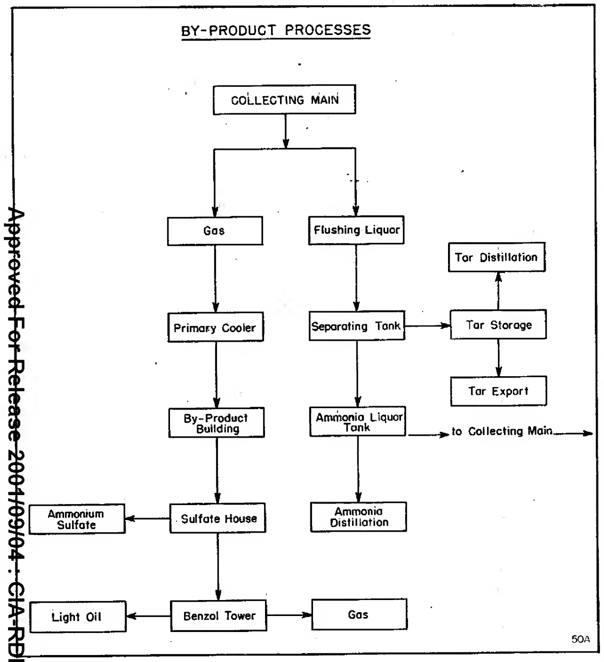
49F

The byproduct plant associated with a chemical works may produce concentrated ammonia solution or liquid ammonia instead of the sulfate, in which case the ammonium sulfate building will be replaced by ammonia scrubbers, concentration, or liquefaction equipment, and storage tanks as shown in the photo below:



49G

The byproduct processes are summarized in the following chart:



The finished products will show considerable variation, according to the degree of processing of the primary products, and the degree of gas purification in the individual plants.

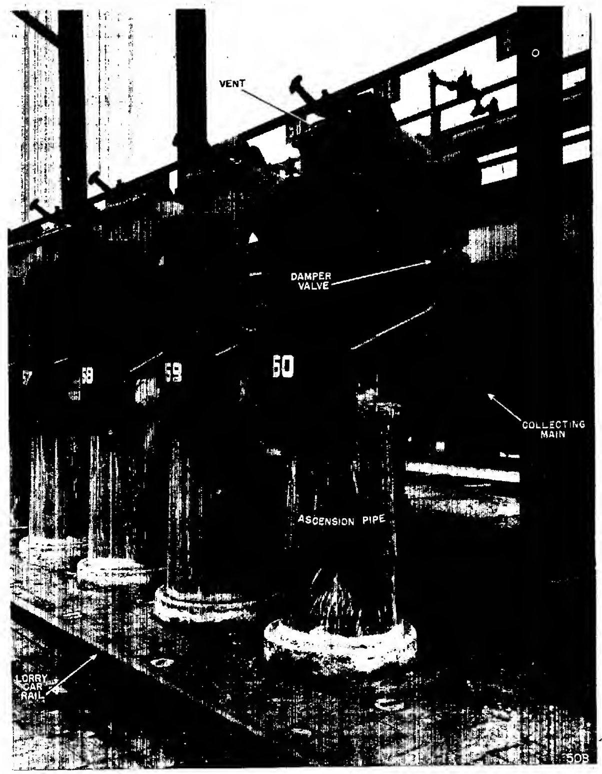
RECOGNITION FEATURES: The more reliable constants for recognition of byproduct plants include: (1) benzol towers, (2) the byproduct building housing exhausters, (3) primary and final coolers and associated water cooling of scrubbing liquids, (4) pipe lines, (5) the decantation group consisting of decanter, ammonia liquor and tar tanks.

Minor identifiable features which may or may not be present include:

(a) Houses:--Ammonium sulphate buildings, tar distillation plants, benzol refinery house.

(b) Outdoor Installations:-- Storage tanks, fractionating columns, sulfuric acid saturators, naphthalene pans.

VULNERABILITY: Destruction of the exhausters and pumps in the byproduct house would bring byproduct recovery to a stop. Effect of such destruction could be minimized by allowing the gas and other volatile constituents of coal to escape into the air through the vents in the coke-oven ascension pipes shown below: (See also Page 12)



These vents are manually operated. It is considered that by allowing such an emergency escape of volatiles it would be possible to continue coking so long as fuel gas for the ovens were available. Thus, ovens using gas from blast furnaces or from an auxiliary water gas plant hypothetically could continue as long as these fuel resources remained operative. Ovens using their own gas could function, of course, only while stored gas lasted. Ovens of some types could be quickly modified to use other gases. (See Fig. 8B for double main construction).

Damage to other units in the byproduct plant might temporarily suspend production, but could probably be speedily repaired by replacement or improvisation. The tanks and mains containing tar, oil, and gas present fire hazard.

PRODUCTION CAPACITY: The capacity of the byproduct plant is normally a function of the number of ovens. The productive capacity can be determined by a count of these ovens.

One ton of coal gives from 7 to 12 gallons of tar, according to the hardness of coal used. The softer coals give the greater quantity of tar. The variation in the composition of coal and diversity of byproduct recovery methods do not permit of precise statistics. The following figures may be considered as a fair estimate of the amounts of primary products from one ton of coal.

Tar - - - - - - - - - - - -10 gallons
Ammonium Sulfate - - - -20 pounds
Light Oil - - - - - - - - - 3 gallons
Gas - - - - - - - - - - - -11,000 cubic feet

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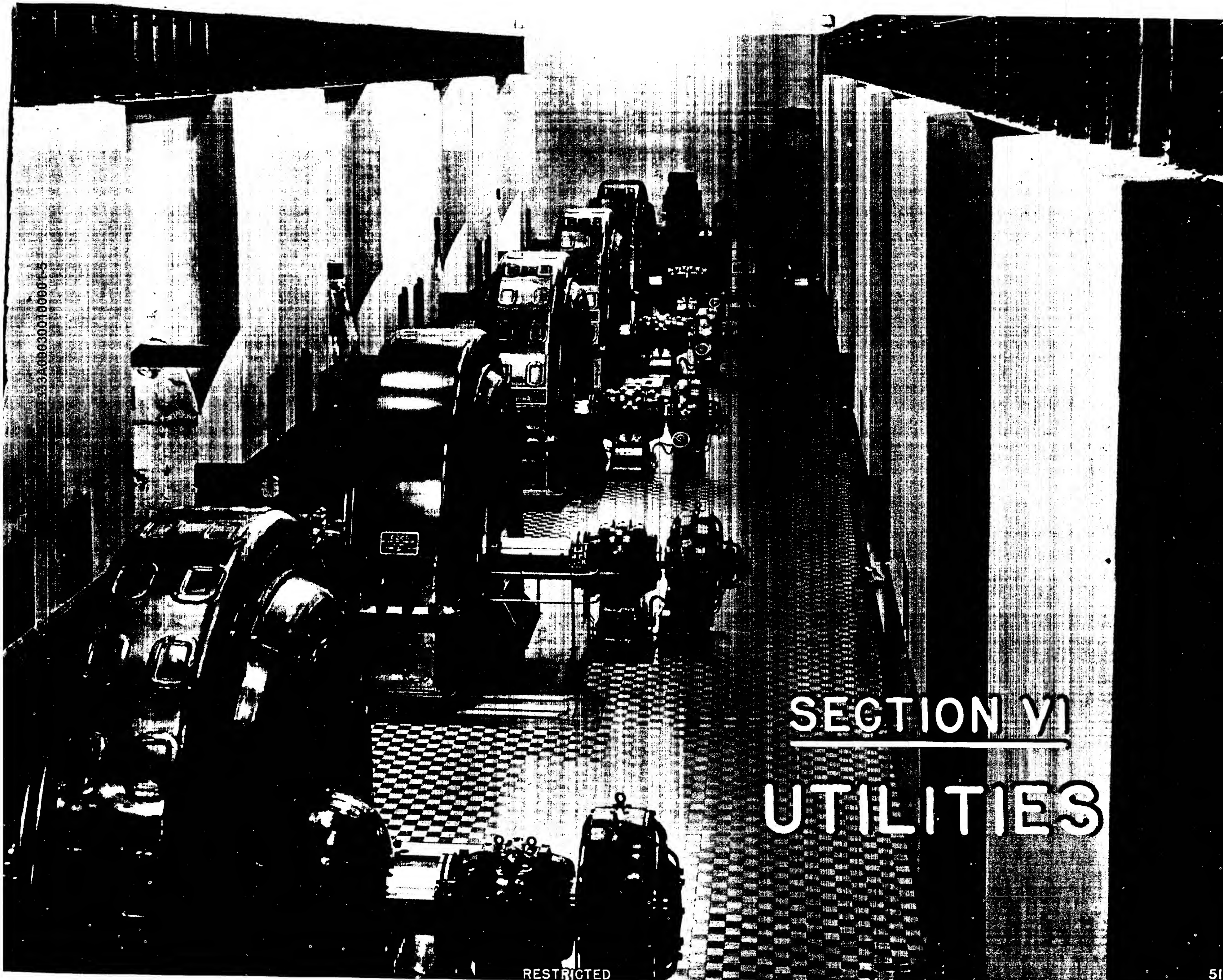


SECTION VI
UTILITIES

IMPORTANCE OF UTILITIES

Water, steam and electric power are essential utilities in the production of coke, iron and steel. The complete interruption of the flow of any of these could stop plant operation and might cause considerable damage.

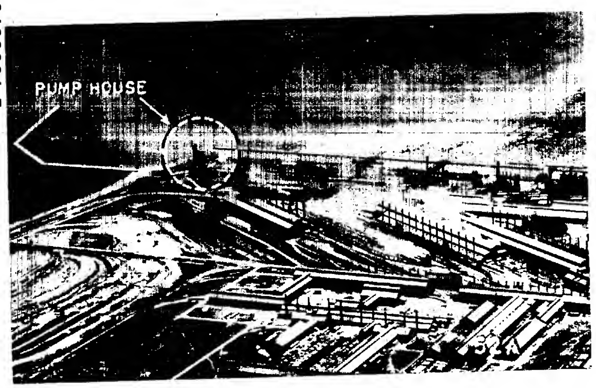
A. WATER

Millions of gallons of water are in daily use in a steel plant. Of this quantity, about 7 million gallons are circulated daily to cool the walls of each blast furnace. If this water supply were cut off for a few minutes, the furnace contours would be destroyed and the brickwork ruined by the terrific heat. This would probably render the furnace inoperative for some months.

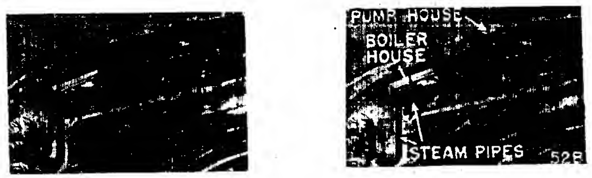
In addition to the above, water is also required for other cooling operations, for the production and condensation of steam, and for miscellaneous plant uses.

THE PUMP HOUSE: Because of the possible damage effected by an interruption of the water supply, pump houses are vital parts of a steel plant. Unfortunately, it is often difficult to pick them out in aerial photography. The pump house is usually small, and of no characteristic design; there are many such buildings scattered around a steel plant. However, the following circumstances may aid in distinguishing it:

1. When the water supply is obtained from a lake, river, or reservoir, the pump house will most likely be on the shore:



A pipeline or scar leading from the pump house to the boiler house and from there to other parts of the plant may be visible. A white plume is sometimes seen in the water near a pump house.



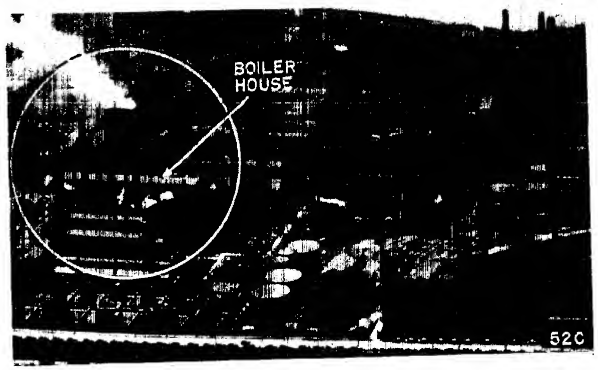
2. When the water supply is located far from the steel plant, at a distant dam for example, a cross-country pipeline or scar leading to a small building may point this out as the pump house.

3. When the piping of a water tank or storage system can be seen to lead to a small building, this may very likely be the pump house.

B. STEAM

Most of the Japanese steel plants so far observed use steam turbines or piston type steam engines to create the air blast for the furnaces. Where such steam driven blasting engines are used, the destruction of their boilers would cut off the air blast, which would of course halt the production of iron until the engines were running again.

The byproduct plant uses steam for the distillation of wash oil from benzol, and for steam jacketed tar tanks and mains. The exhausters and pumps may also be steam driven. This boiler house supplies steam to a byproduct plant:



Japanese steel plants also use steam to generate electric power.

The fuel burned under the boilers to create steam may be coke oven gas, top gas from the blast furnaces, or coal or coke breeze, which is the fine dust screened from the coal or coke. For a description of boiler houses, see "Power Plant" below.

C. ELECTRIC POWER

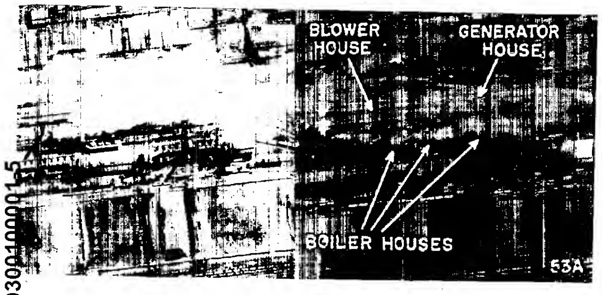
The electric power systems of all Japanese steel plants are connected with outside power networks. Thus, in case of failure of the plant generators, some or all of the required power could be drawn from outside sources. However, in several instances the older portions of such plants contain equipment designed to operate at a frequency different from that which the network supplies, and thus elimination of the power sources within these plants might make it impossible to operate certain of these old units.

Electric power is used to drive the motors which operate the steel mills, blast furnace skip hoists, conveyor systems, coke-oven lorry cars, pushing rams, cranes and pumps, and also for the electric furnaces where present.

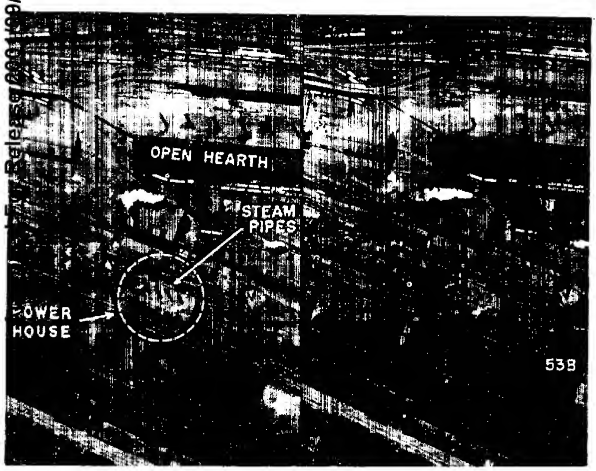
THE POWER PLANT: Reference to the buildings which house boilers and generators is often made too casually. They are variously called "power plants," "power houses," "boiler houses," or even "engine houses." Since steam and electricity are both power media, the buildings in which they are both produced will be designated as a *power plant* in this and future Photo Industrial Studies. In cases where the steam and electricity are produced in separate buildings, each structure will have an individual designation, as *boiler house* for steam, and *generator house* for electric power. Boiler and generator houses in association may be referred to as a *power plant*.

More than one boiler house is usually provided to supply the various units of a steel plant. One or more of these may supply steam to electricity generators housed in the same or a nearby building. When the generators are placed in a boiler house, which thus becomes a power house, the room in which they are

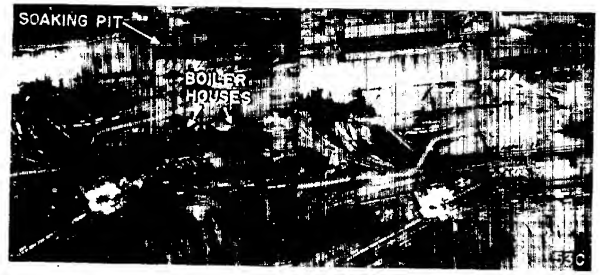
placed is known as a *generator hall*. The blast furnace plant shown in the stereogram below has several boiler houses, one of which supplies the generators in the adjoining generator house:



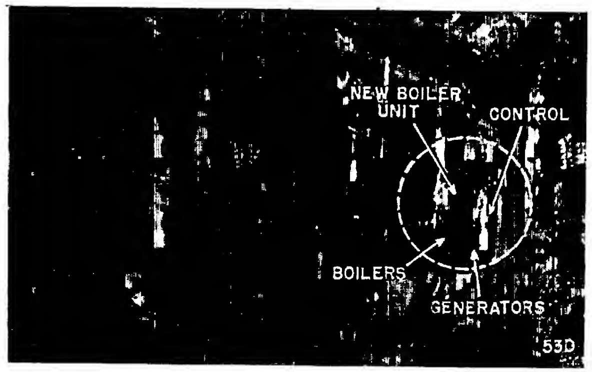
The typical older Japanese boiler and power house had one or two large concrete chimneys detached from the building, but newer installations have short steel stacks along one side of the roof at one end of the boilers. Each stack represents one boiler or sometimes two boilers. The stacks are more closely spaced than those associated with other steel plant units such as soaking pits and open hearth furnaces. The difference in spacing between open hearth and boiler stacks may be seen in the aerial view below:



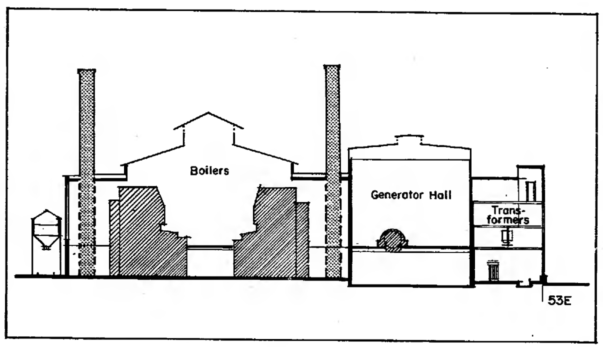
A comparison between boiler house and soaking pit stacks is given in the photograph at the top of the next column of this page.



In Japanese power houses the boilers may be placed in a single or double row. The stacks of double row installations are built along the outer edge of each boiler bay, as shown in this stereogram of the No. 4 power house at Yawata:

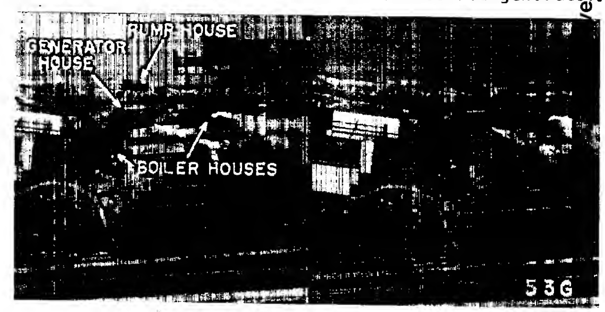


The following section through the power house above gives an idea of the relation between boiler room, generator hall, and transformer or control room.



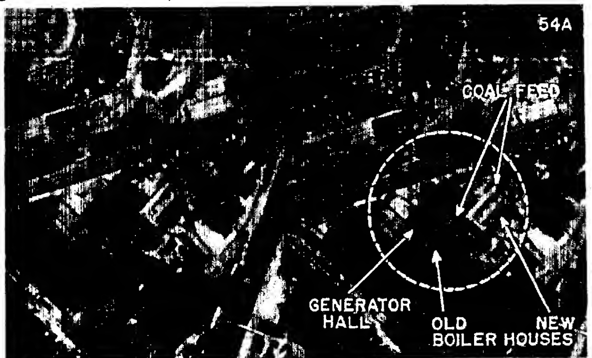
The power house of the steel mill at Tobata, Kyushu, is typical of the larger Japanese power houses with a single row of boilers. Its dimensions, which are not exceeded by any known power house associated with a Japanese steel plant, are approximately: 225 feet wide and 370 feet long. The stacks are about 60 feet apart, and represent one large boiler apiece. Here it is in vertical stereo:

In identifying the buildings connected with the production of electric power, it must be remembered that closely spaced stacks or possibly one or two large stacks associated with a suitable building merely indicate the presence of boilers. A neighboring stackless building of approximately the same size may reasonably be assumed to house the electric generator.



In the absence of such a building, that part of the power house not served by stacks will probably be the

generator hall, as illustrated in the following stereogram of a Yawata power plant:



The stackless building adjacent to the annotated generator hall is believed to contain additional generators for the new boiler unit.

When the boilers are fired with coal, grinding or pulverising equipment and conveyors may be at the end of the boilers opposite the stack. When the boilers are in double row, such equipment will usually operate through the center lane between the boilers.

In addition to the water which is converted into steam, power plants require large amounts of cold water for cooling purposes. This is especially true of steam turbine installations, which make use of condensation to utilize more fully the energy in steam. Where a large natural body of water is not available, the water circulated through the condensers may be conserved and recycled by the use of such cooling systems as spray ponds, or cooling towers of the cascade or cylindrical type. These installations are described in Photo Industrial Study No. 2, page 30, and may aid in the identification of power plants. The stereogram below shows cylindrical cooling towers at the blast furnace power plant at Anshan, Manchuria:

POWERHOUSES SERVING THE OLD BLAST FURNACE PLANT AT PENHSIHU, MANCHURIA.

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SECTION VII

TRANSPORTATION

OF RAW MATERIALS

IMPORTANCE OF TRANSPORTATION

Transportational facilities are especially vital to the Japanese steel industry, because Japan proper contains almost no iron nor coking coal deposits. A study of raw material transportation provides the photo interpreter with useful indications on production. Therefore, although a complete description of bulk mineral transport is beyond the scope of this Study, the following summary is included to supplement the account of coke, iron and steel.

METHODS OF TRANSPORTATION

Coal, ore and limestone in transit are handled with very similar equipment, so that a description of the methods used to transport one mineral will generally apply to the other. The transfer of *coal* and *ore* from mines to plant comprises a long series of loadings, shipments and unloadings, requiring more or less elaborate and diversified means. The *limestone*, on the other hand, is often quarried close to the plant, and only a comparatively small amount is needed. Thus limestone presents a very minor handling problem, and will be only briefly mentioned.

The journey from the mine to the plant may be divided as follows:

A. Loading at the mine

B. Transporting from mine to plant
   1. Rail transport
   2. Water transport

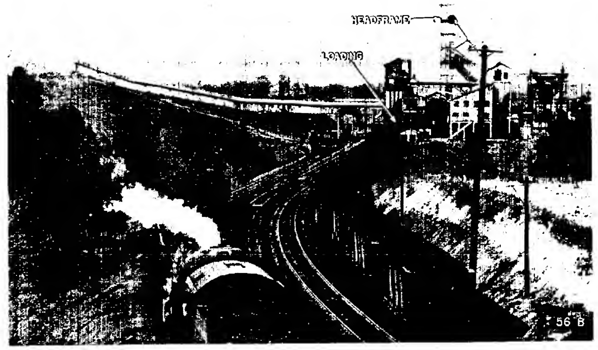
C. Unloading at the plant
   1. From rail transport
   2. From shipping

A. LOADING AT THE MINE

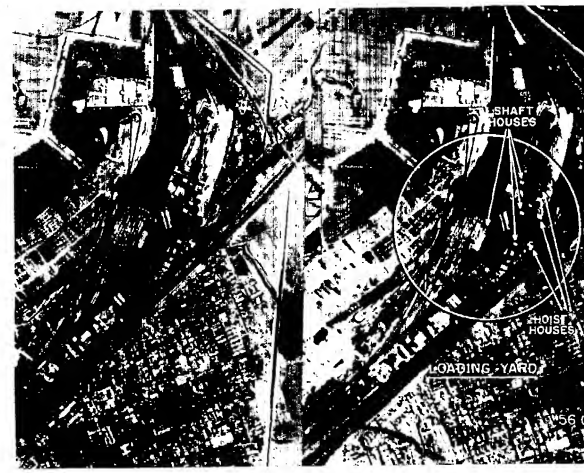
The mines themselves may be either open cut or underground. Generally speaking, in the Far East, iron ore is most often extracted from open pits and coking coal from shaft mines. Limestone quarries, of course, are also open workings.

In shaft mining the coal is brought to the surface in buckets, skips or cages, which are pulled up the shaft by a hoist. The framework over the shaft is called a *shaft house* or *headframe*. Inclined braces supporting the headframe extend toward the *hoist house*, which contains the hoisting machinery. The coal will probably travel by conveyor through some preparatory treatment such as screening or washing, before it is loaded.

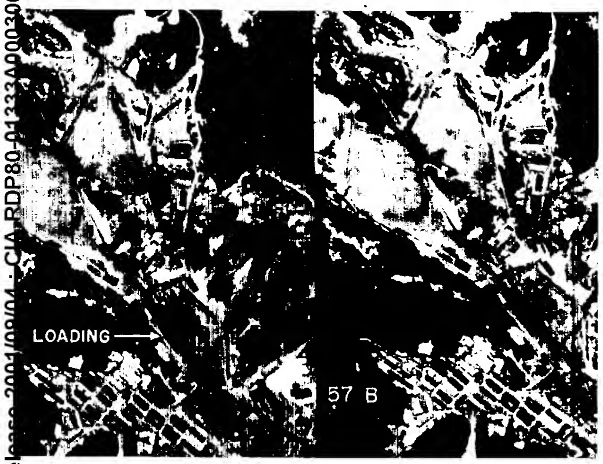
Both coal and ore almost invariably leave the mines by some form of rail transport, except in one or two cases where the mines are so close to the plant that a conveyor system is practicable. The following ground views show rail loading facilities at mines:



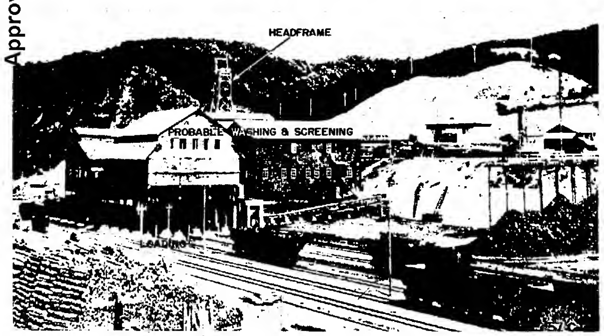
The rail loading yard will form a useful recognition feature for shaft mines when seen in aerial photography, as illustrated in these stereograms of coal mines at Linsi, China:



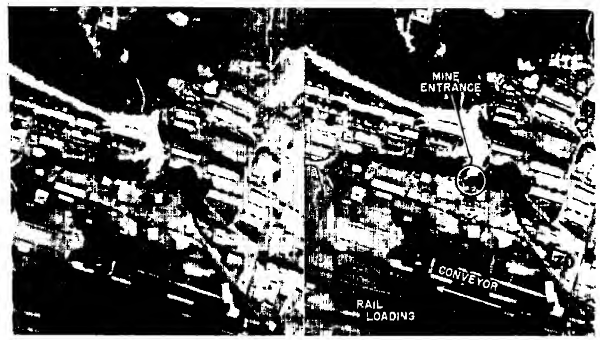
In the case of small shaft mines, such as these coal workings near Fukuoka, Kyushu, the loading sidings are particularly helpful indications:



Such mines are generally served by their own narrow gauge feeder railroads. Here is a ground view of a similar mine in the same area:

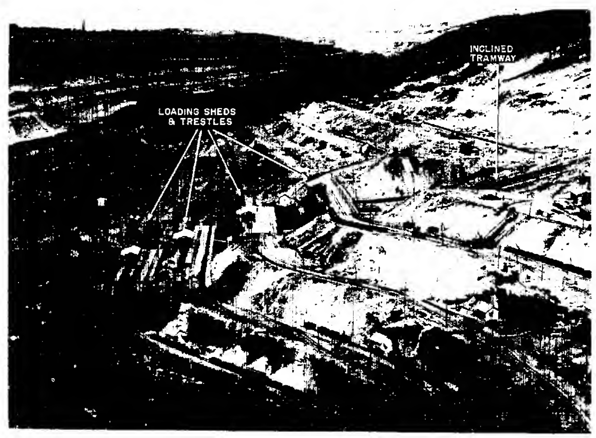


Where underground workings are reached by a tunnel instead of a shaft, the coal may be trammed out. The tunnel entrance to a coal mine at the old smelter at Penhsihu, Manchuria is shown below:



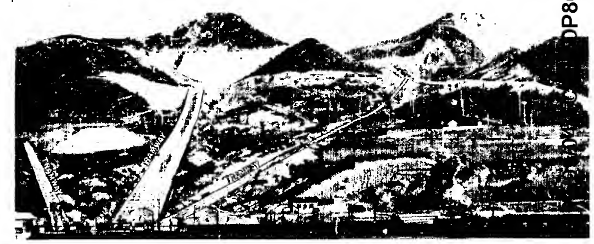
Here some of the transportation is probably accomplished by manual labor. The photograph above also contains a conveyor system which carries coal to the plant storage area. This plant is shown more fully in Section VIII--Annotated Examples.

In large open cut mines or quarries a railroad system will usually be constructed within the excavation. The rails are laid on the benches or levels, as shown in these open workings in Fushun, Manchuria.

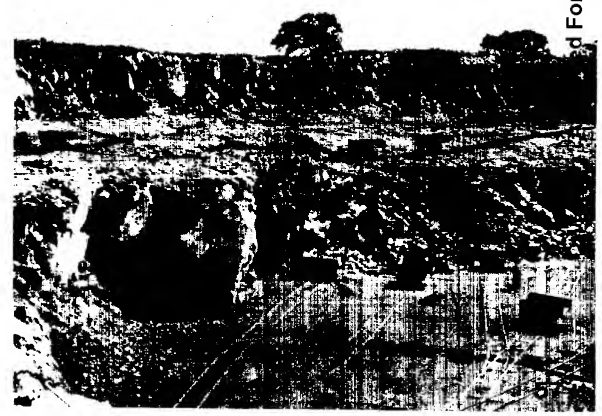


This particular pit produces non-coking coal, but the view gives a good idea of transportation in a large open cut mine. The view at the top of the next column shows ore trains in a domestic iron mine:

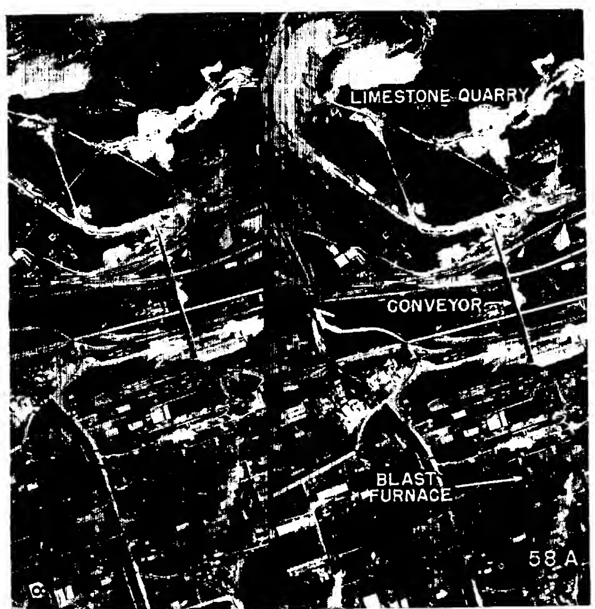
In the Far East, electric tramways may be used to carry the ore from the mining level to hoppers where it is loaded into railroad cars. Such tramways may be seen in the following general view of the iron mines near Anshan, Manchuria:



In limestone quarries the equipment is generally limited to small cars or trams as shown in this ground photo of a quarry containing a type of limestone ore:



Where the quarry is adjacent to the plant, conveyors may be used. The following vertical stereogram of the limestone quarry at the new blast furnace plant at Penhsihu, Manchuria, illustrates such a conveyor system:



B. TRANSPORT FROM MINES TO PLANT

This phase of the journey may be comparatively short when the plant is built near usable coal or iron deposits, as is sometimes the case on the Asiatic mainland. Plants in Japan proper, however, are obliged to import one or both of these minerals over considerable distances by rail and water. This long supply route renders the production of iron and steel in Japan proper unusually dependent on transportation facilities.

RAIL TRANSPORT: The railroads of Japanese occupied territories vary widely in gauge and in size and type of rolling stock. Following are some general statistics by area:

KYUSHU - SHIKOKU - HONSHU - HOKKAIDO

Mainline gauge:	3 feet 6 inches (so-called "meter")
Industrial feeder line gauge:	2 feet 6 inches or less
Average gondola capacity:	10 to 13 tons
Average gondola length:	20 to 30 feet

Rolling stock resembles European; cars are small; 4-wheel cars common.

MANCHURIA - CHINA
(Japanese occupied)

Mainline gauge:	4 feet $8\frac{1}{2}$ inches (U.S. standard)
Secondary mainline gauge:	Same
Average gondola capacity:	15 to 35 tons
Average gondola length:	34 feet

Rolling stock resembles that of U.S.; good quality modern equipment and roads; many cars with 4-wheel trucks.

THAILAND - BURMA - FEDERATED MALAY STATES - FRENCH INDO-CHINA

Mainline gauge:	Almost entirely 3 feet 3 3/8 inches (true meter)
Some mine roads running to ports:	2 feet 6 inches

Rolling stock resembles Japanese in size and capacity.

SUMATRA

Gauge:	3 feet 6 inches with exception of Atjeh line in NE which is 2 feet, 6 1/3 inches.

Rolling stock resembles Japanese.

JAVA

Gauge:	Majority is 3 feet 6 inches with exception of one NS line across center of island which is U.S. standard.

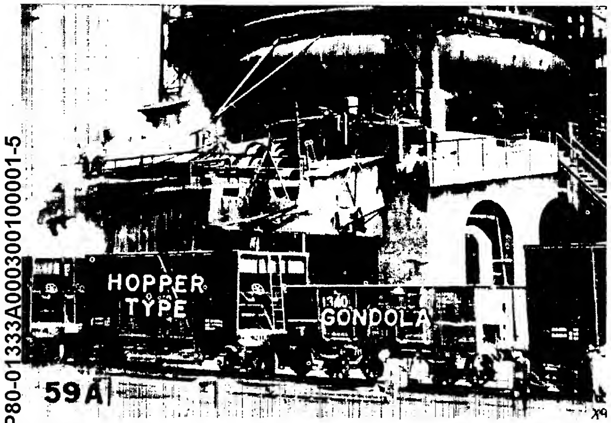
Rolling stock resembles Japanese.

FORMOSA

West coast gauge:	3 feet 6 inches
East coast gauge:	2 feet 6 inches

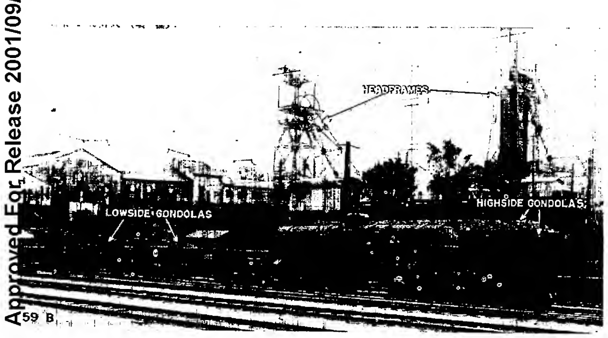
Rolling stock resembles Japanese.

Throughout the Far East in general, the *gondola* as well as the *hopper car* is used for bulk mineral transport. Both are shown in this photograph at Anshan, Manchuria:



59A

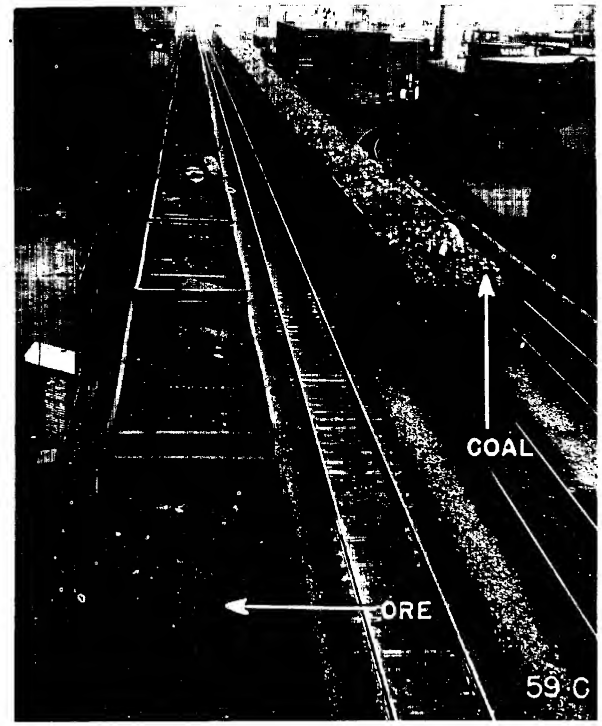
Gondolas are divided into high side and low side cars, the use of which depends upon the capacity of the roads and bridges. Examples of both types can be seen in this ground view of a coal mine at Fushun, Manchuria:



59 B

Some Far Eastern gondolas, like those shown above, have wooden sides.

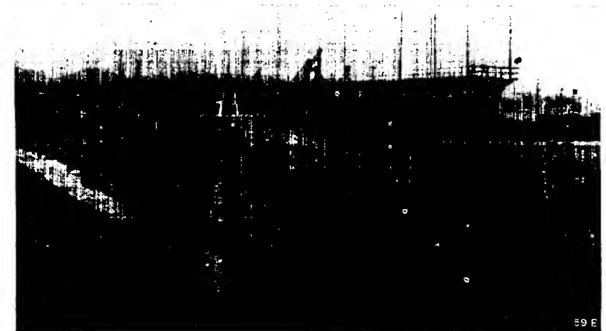
Ore and coal trains may be distinguished in aerial photographs by the fact that they will rarely contain other than open cars. While ore frequently appears lighter than coal in photographs, both materials vary widely in tone, and it is impractical to attempt to distinguish between them. Their similarity is illustrated in the photograph at the top of the next column:



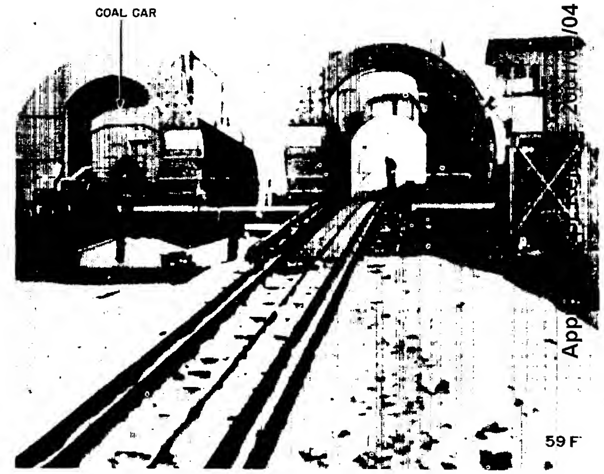
59 C

Limestone, of course, is readily distinguished by its whiteness. Cars filled with coal, ore and limestone may be seen in this view of the marshalling yard of a domestic steel plant:

WATER TRANSPORT: When coal and ore are to be transferred to ships or barges, they will pass through more or less elaborate port loading yards. The trestles of a large depot behind the quay wall at Miike, Kyushu are shown in this photograph:


59 E

A modern unloading device appears at the coaling port of Muroran, Hokkaido, where the cars are run onto rotating drums and dumped by rolling them upside down.

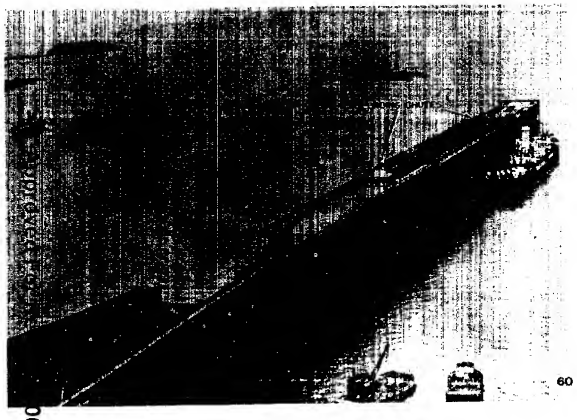


59 F

Loading Equipment: Many different types of loading equipment are used in the Far East. A few of these are illustrated below. Several of the photographs were taken at coal bunkering ports which load coal for fueling purposes but the equipment shown may be regarded as typical bulk mineral loading machinery.

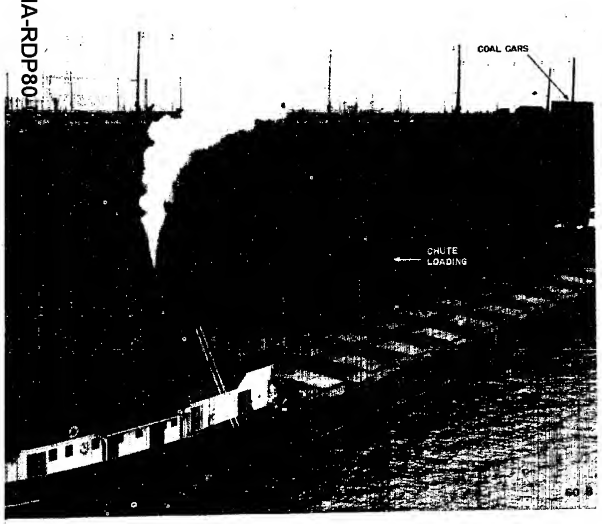
TRANSPORTATION

The most striking of such installations are the chute-loading piers, one of which is seen at the coaling port of Muroran:



60 A

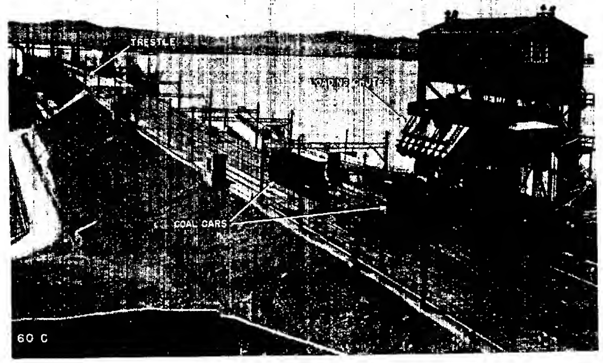
Here, cars carry the coal out onto the pier where it is loaded into the vessel through chutes on each side of the pier. This next photograph gives a close-up of such chutes:



60 B

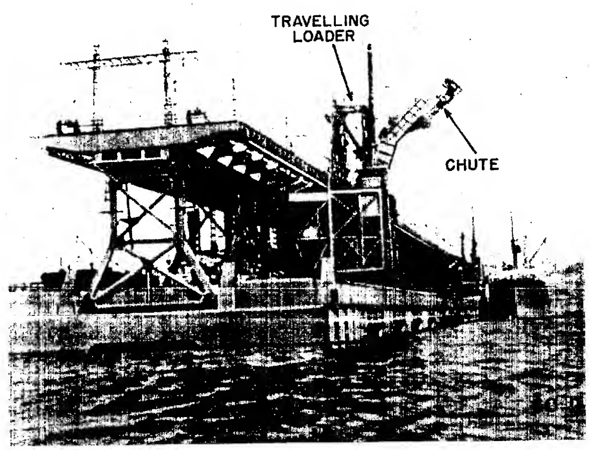
Exactly similar piers are also used for loading ore as well as coal in this country, but it is not known whether the Japanese have found occasion to construct chute-loading piers for ore transfer.

Another type of coaling pier is found at Kanseishi, near Dairen, Korea. Here the coal is also carried out by rail:



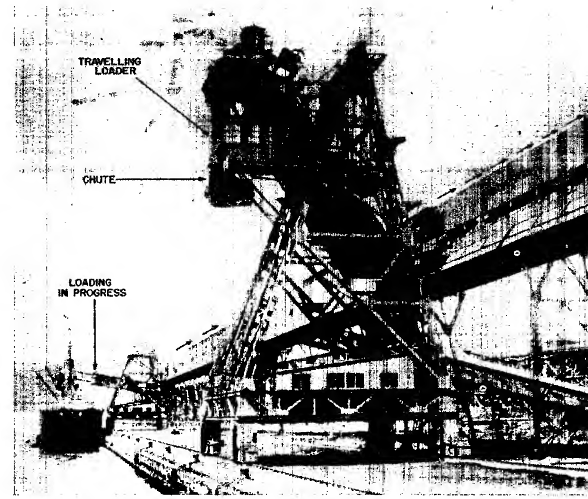
60 C

The coal is then dumped through the trestle to be picked up by travelling loaders which ride on rails on each side of the pier.

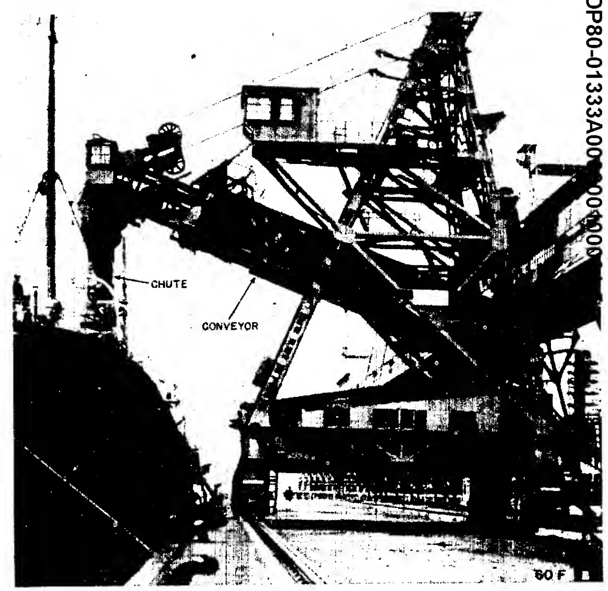


The mobility of the loading mechanisms permits vessels to come alongside the pier without the careful maneuvering necessary to load from stationary equipment.

A similar type of loader operates along the quay at Muroran:



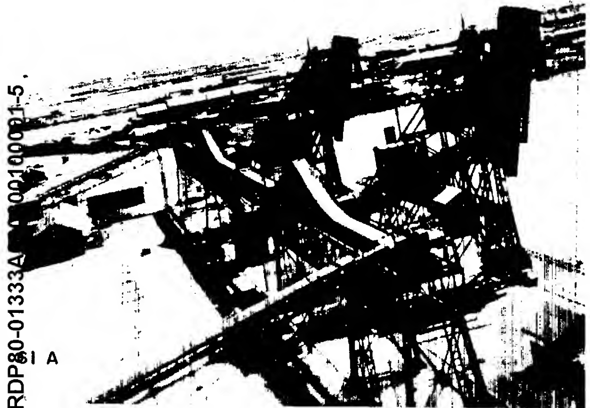
These are fed by a conveyor system. Coal being loade[d] into a ship may be seen in the background of the above photo. The loading arm carries a conveyor and chute which is lowered into the vessel's hold. Here is close-up:



60 F

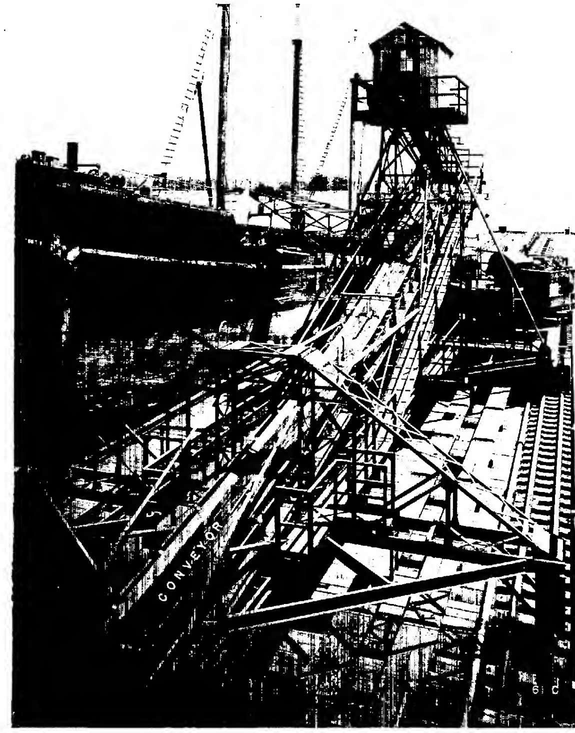
RESTRICTED

The similarity between ore and coal loading equipment is illustrated by this photograph of the iron ore loading pier at Bakli Bay, Hainan Island:

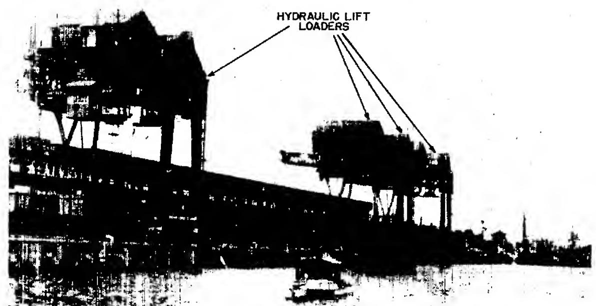


This pier handles the ore by means of long conveyors and travelling loaders comparable to those for coal shown above. This equipment is very distinctive in vertical view.

At the top of the next column is a close-up of a domestic coal loading conveyor system, which gives an idea of the machinery.



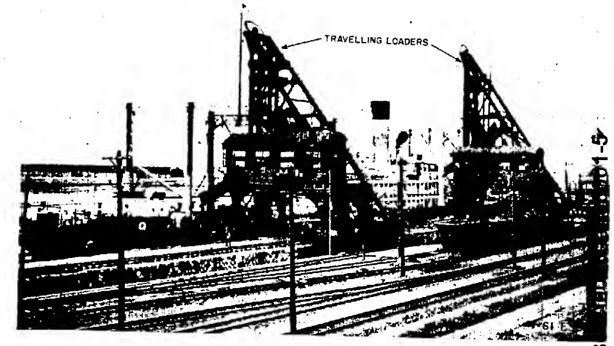
The photograph below shows the hydraulic coal lifting towers installed at the coaling docks near Wakamatsu, Kyushu:



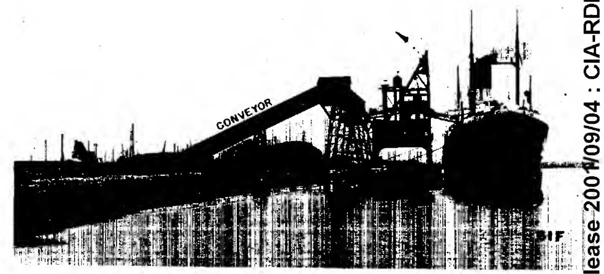
61 D

These have retractable extensions which appear to support travelling cranes.

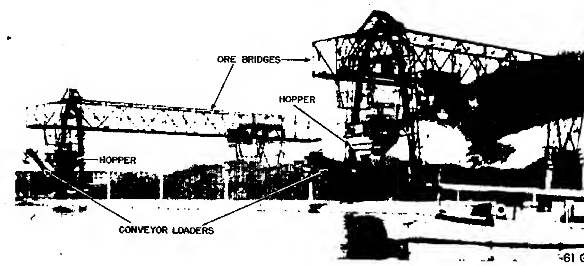
There are many variations of the loading devices shown above, but they all operate on the same general principles. The photograph below shows the large travelling coal loaders at Miike, Kyushu:



which may be fed from railroad trestles or from stationary conveyor system:



Still another type of loading equipment is used Muroran, the travelling ore bridge which loads coal direc from storage through its own hoppers and conveyors:



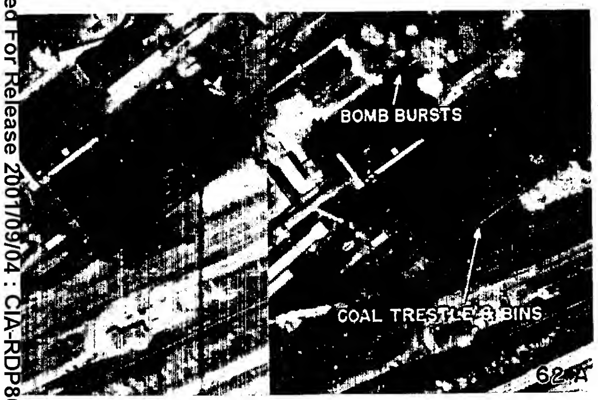
In addition to the large mechanisms shown above, the interpreter should be prepared to find loading operations carried on by the vessel's own winches, or by stevedore labor.

RESTRICTED

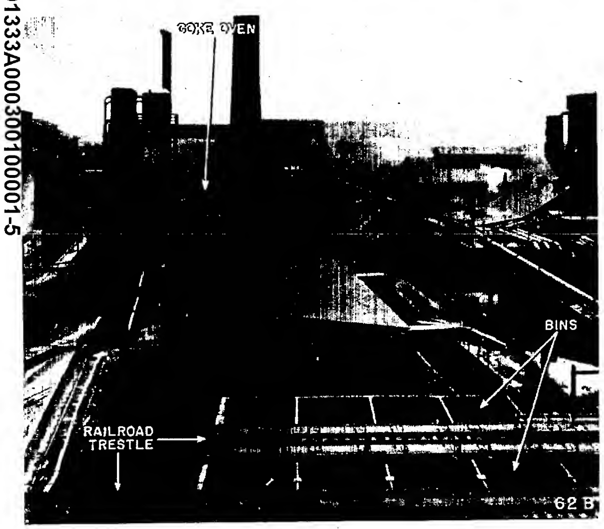
Shipping: For a description of the colliers, ore boats and other cargo vessels used to transport coal and ore, the reader is referred to Recognition Manual 208-J Revised, issued by the Office of Naval Intelligence. Examples of ships and barges carrying coal and ore appear in photographs below.

C. UNLOADING AT THE PLANT

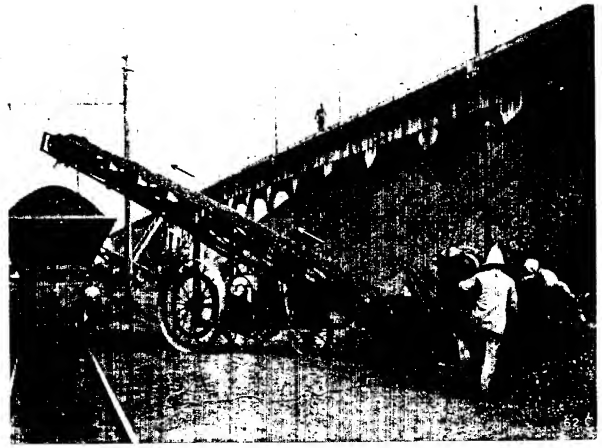
FROM RAILROAD TRANSPORT: When the coal or ore arrives at the steel mills by rail, it is generally unloaded through trestles like these at the coking plant at Anshan. Manchuria:



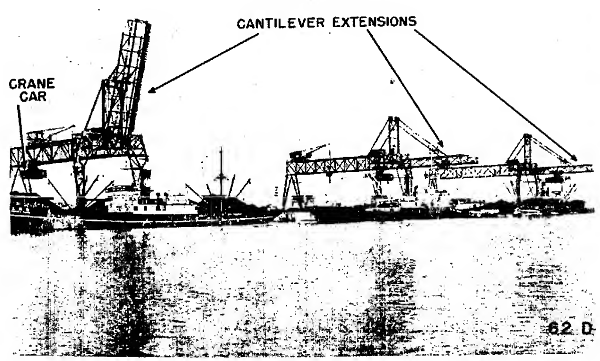
Here is a close-up of similar bins at a German coke oven:



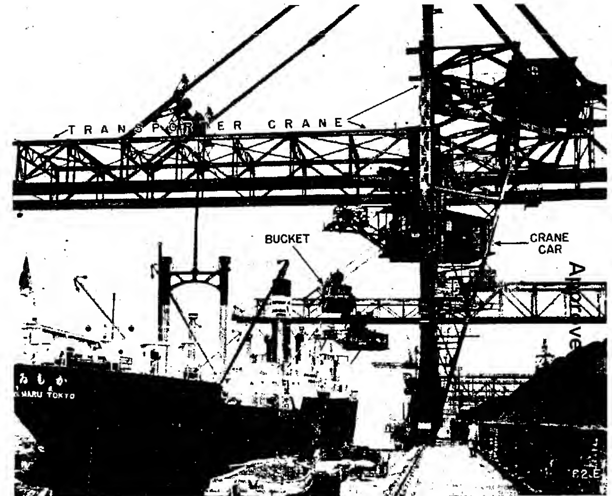
The ore and coal may also be dumped in the open and then removed by a conveyor or by mobile equipment. A common type of mobile conveyor is shown below:



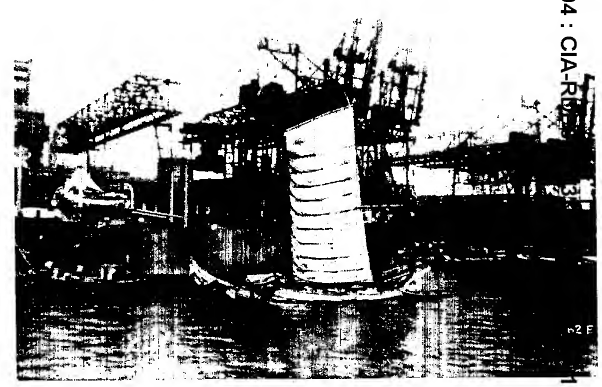
FROM SHIPPING: Frequently, the same type of dockside cranes can perform both loading and unloading operations. The giant transporter-cranes shown below at Kawasaki, Honshu are of this type, although they are principally used for discharging bulk cargo:



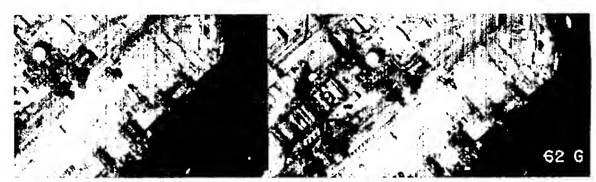
The photo shows the cantilever extensions on which the crane car and bucket can ride out over the ship. A small derrick travels on the top rails, over the stock pile.



This type of crane is evidently popular in Japan. At the harbor of Yawata, Kyushu they are used for unloading ore as shown below:

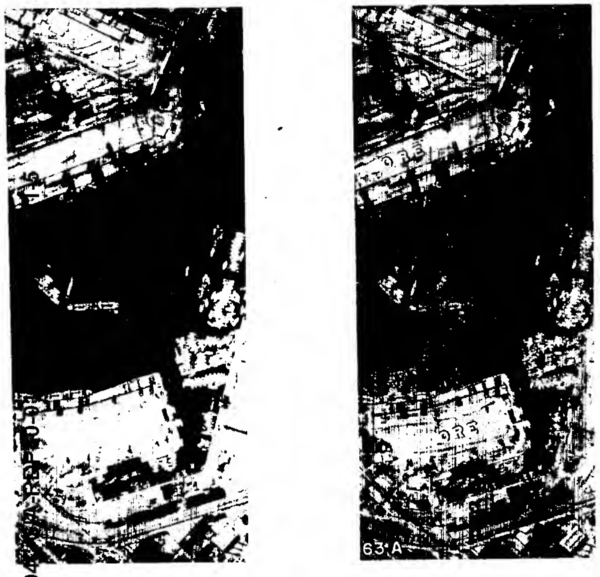


The new blast-furnace plant, across the harbor from the old works, can be discerned in the background
Here is a view of the same wharf in vertical stereogram:

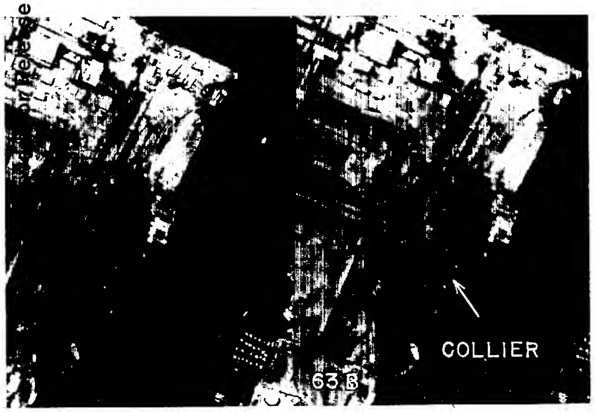


RESTRICTED

The following general vertical view of the Yawata harbor shows the ore unloading equipment on the quay, and also lightering operations in progress.

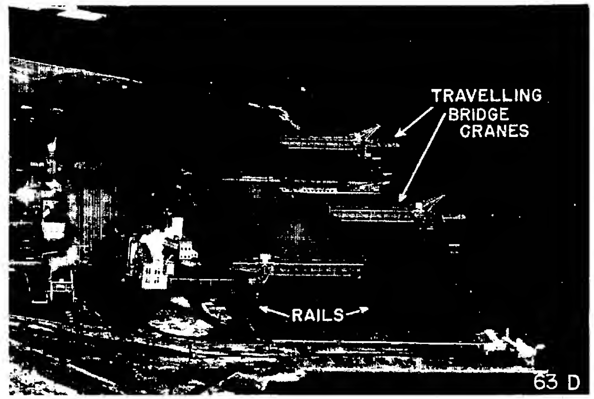


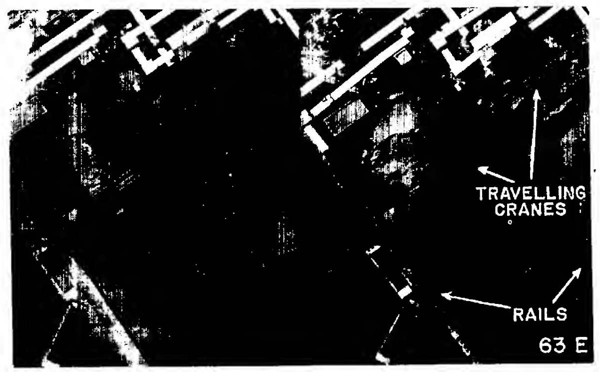
Coal unloading is carried on at the new coke plant across the harbor, where a collier may be seen discharging its coal. Here is an enlargement of the upper right corner of the preceding stereogram:



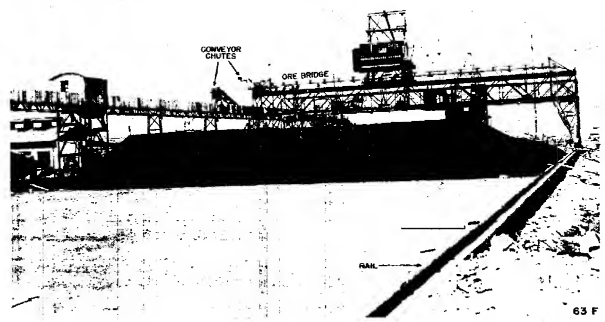
The cranes used here are apparently ordinary dockside cranes with revolving booms. It seems probable that the construction of travelling ore bridges was contemplated at this storage site.

Two typical modern coal unloading and storage installations are shown in the aerial photographs below. The travelling transporter cranes may be linked to allow the crane car to travel across both piles.

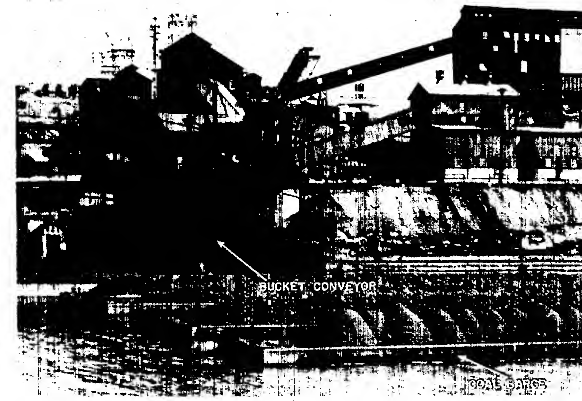




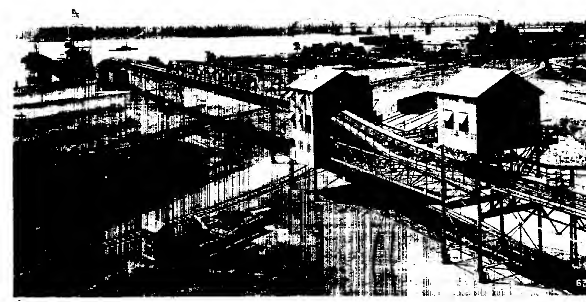
A similar bridge transporter which is fed by a conveyor system appears at Tsurumi, Honshu:



Occasionally a bucket conveyor with stationary framework may be used for the complete unloading operation, as shown below.



This photograph is a ground view of the vertical stereogram 5D on page 5. Here is another example of a conveyor system which carries the coal from the unloading wharf.



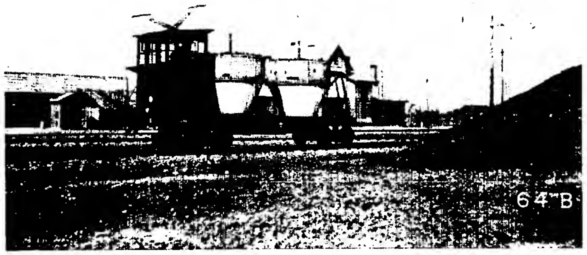
Since much of the development of Japanese port facilities has taken place in recent years, the precise extent of mechanization is not known. However, the abundant supplies of cheap labor available in the larger cities of Japan tend to counteract the economic advantage of very elaborate installations. At the port of Nagasaki, for example, virtually no large bulk cargo handling facilities had been installed as late as five years ago and unloading was accomplished by ships' winches and stevedore gangs. There appears to be a correlation between the density of the local population and the character of port facilities; for instance, on Hokkaido which is not favored as a dwelling place by the Japanese, considerable mechanization of bulk cargo operations is found.

In estimating the importance of loading and unloading equipment, the interpreter should always consider that in many cases the vessels can transfer their cargoes by using their own winches. When available stevedore labor can usually be substituted for damaged mechanical devices without very great loss of efficiency. Furthermore, the present unfavorable shipping situation of Japan reduces the importance of large installations designed to operate at a maximum capacity far beyond the demands which they are probably now being called upon to fulfil.

COKE

In most cases it is only necessary to carry coke from the ovens to the blast furnace within the plant which may be done by means of a conveyor system, as shown in this photograph of the new coke plant at Yawata:

or by such coke cars as this one in Anshan:

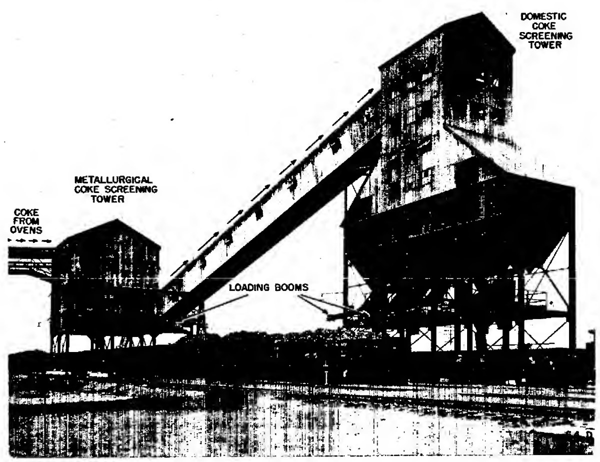


However, blast furnace plants in Japan proper may require more coke than is produced in the immediate vicinity. In these circumstances coke will be imported in the same manner as coal or ore.

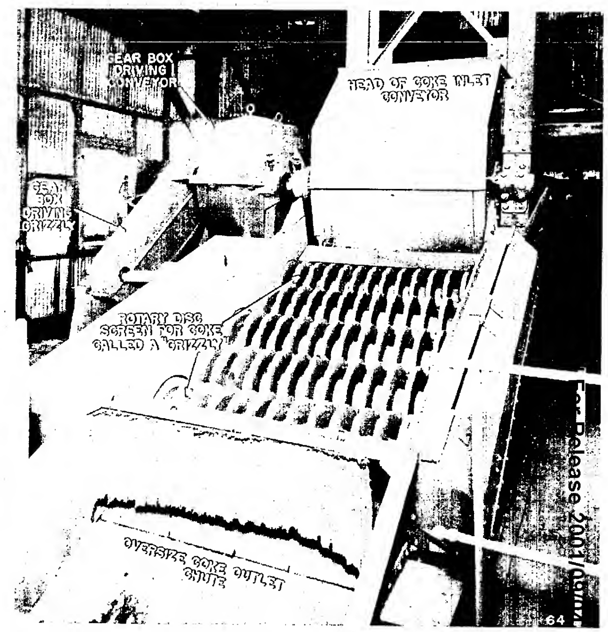
The stereogram below gives a ground view of coke being loaded into railroad cars.

Where two screening and loading installations are found, two distinct grades of coke are sometimes being handled. Such an instance is illustrated in the domestic view below. Here metallurgical coke screening is seen in one tower, while domestic coke is handled in another.

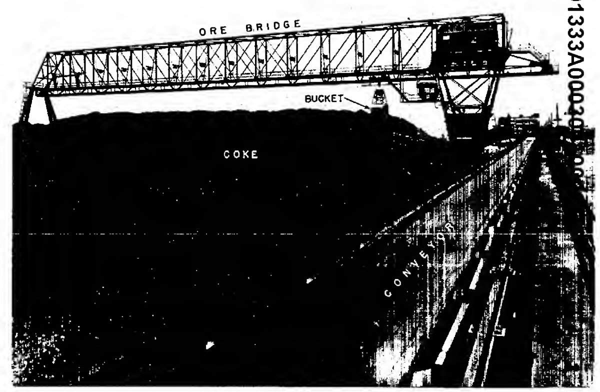
SCREENING AND LOADING OF DOMESTIC AND METALLURGICAL COKE



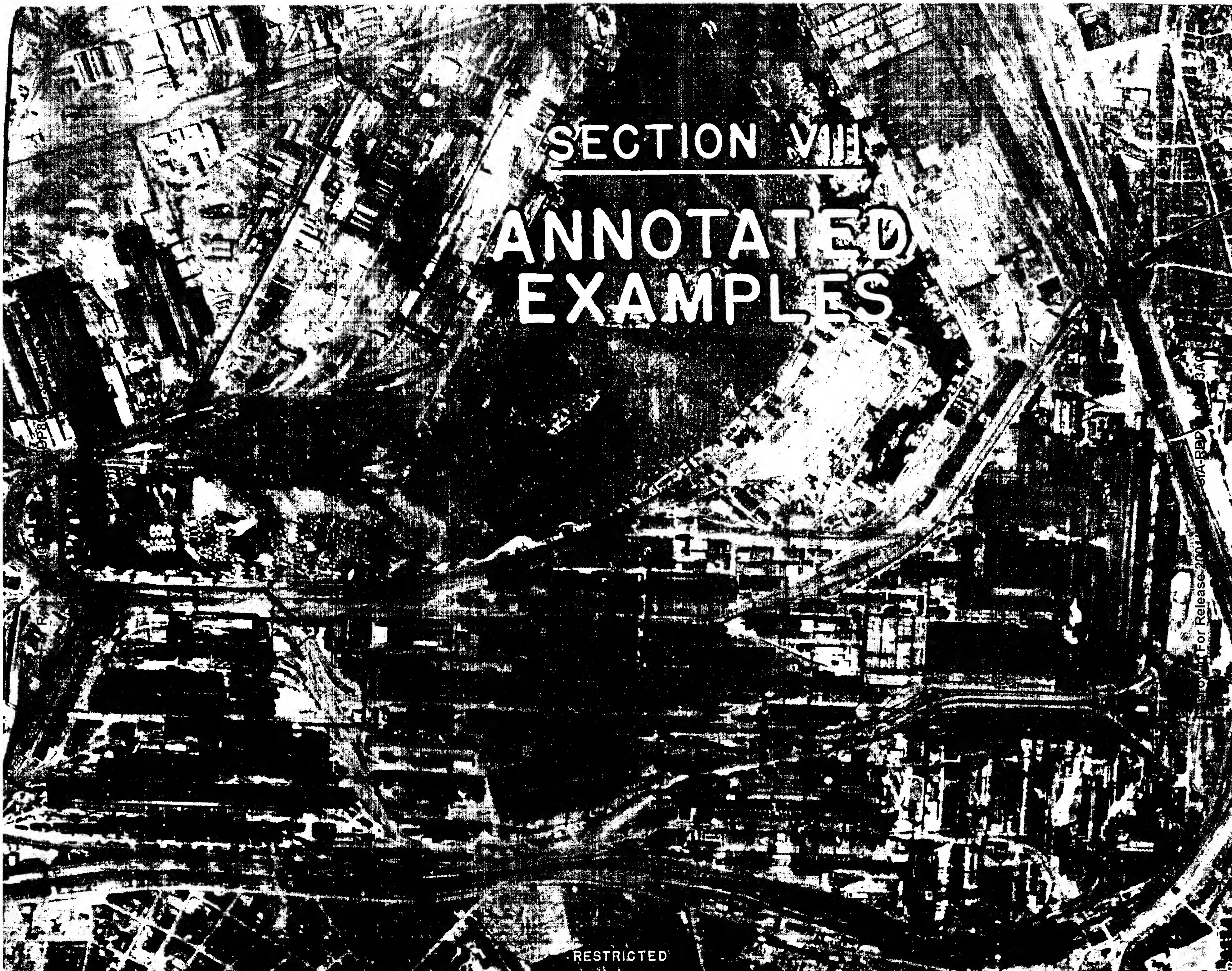
At the top of the next column is an interior view of a coke screening tower showing a screen of the rotary disc type.



Coke in storage is handled with the same type of equipment as ore and coal, as shown in this view of a coke pile with transporter crane and conveyor belt.

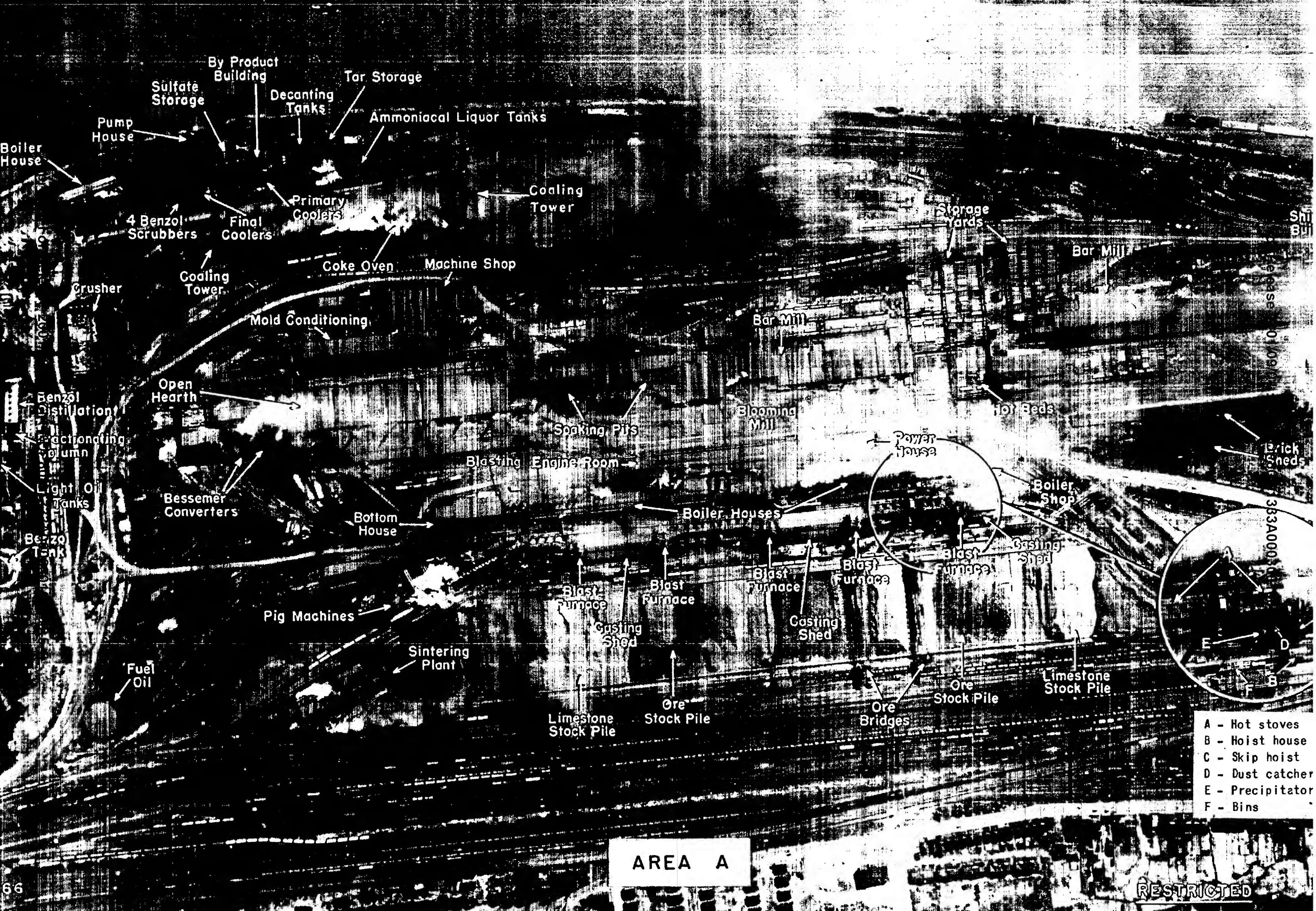


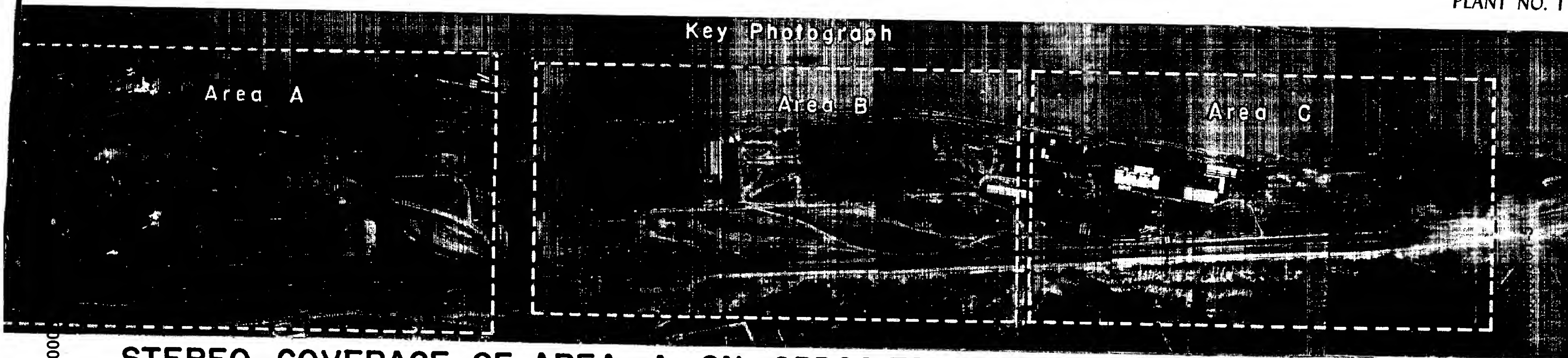
However, since coke is porous and breakable in structure, unnecessary handling is avoided. Coke is generally consumed about as quickly as it is produced, and therefore coke storage will not approach the quantity of storage of ore and coal.


SECTION VIII
ANNOTATED EXAMPLES
RESTRICTED

PLANT No. I

EXAMPLE OF A LARGE INTEGRATED STEEL WORKS

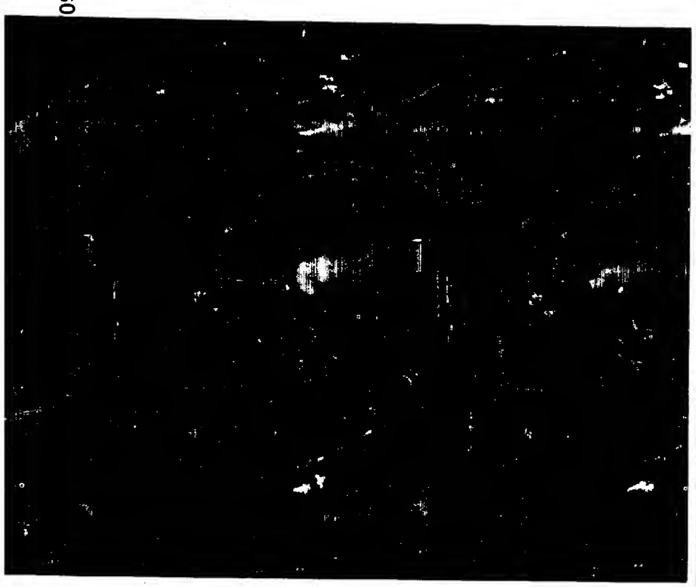


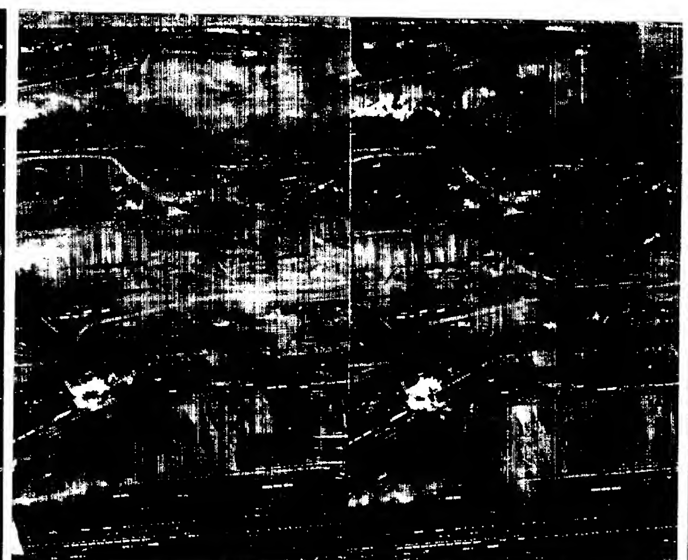


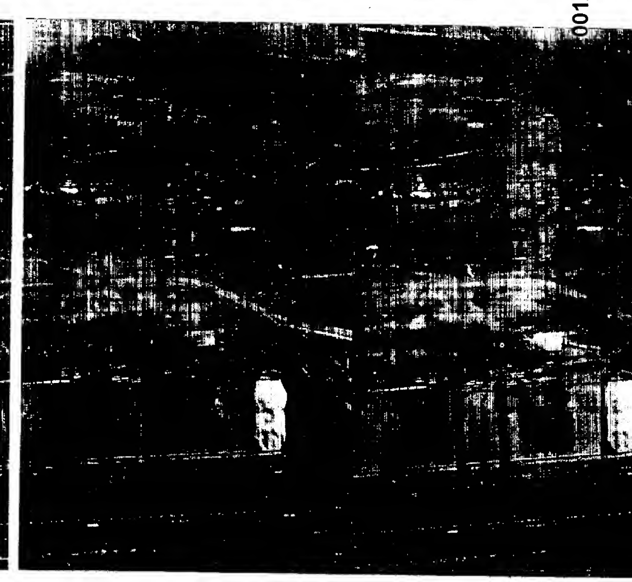
STEREO COVERAGE OF AREA A ON OPPOSITE PAGE

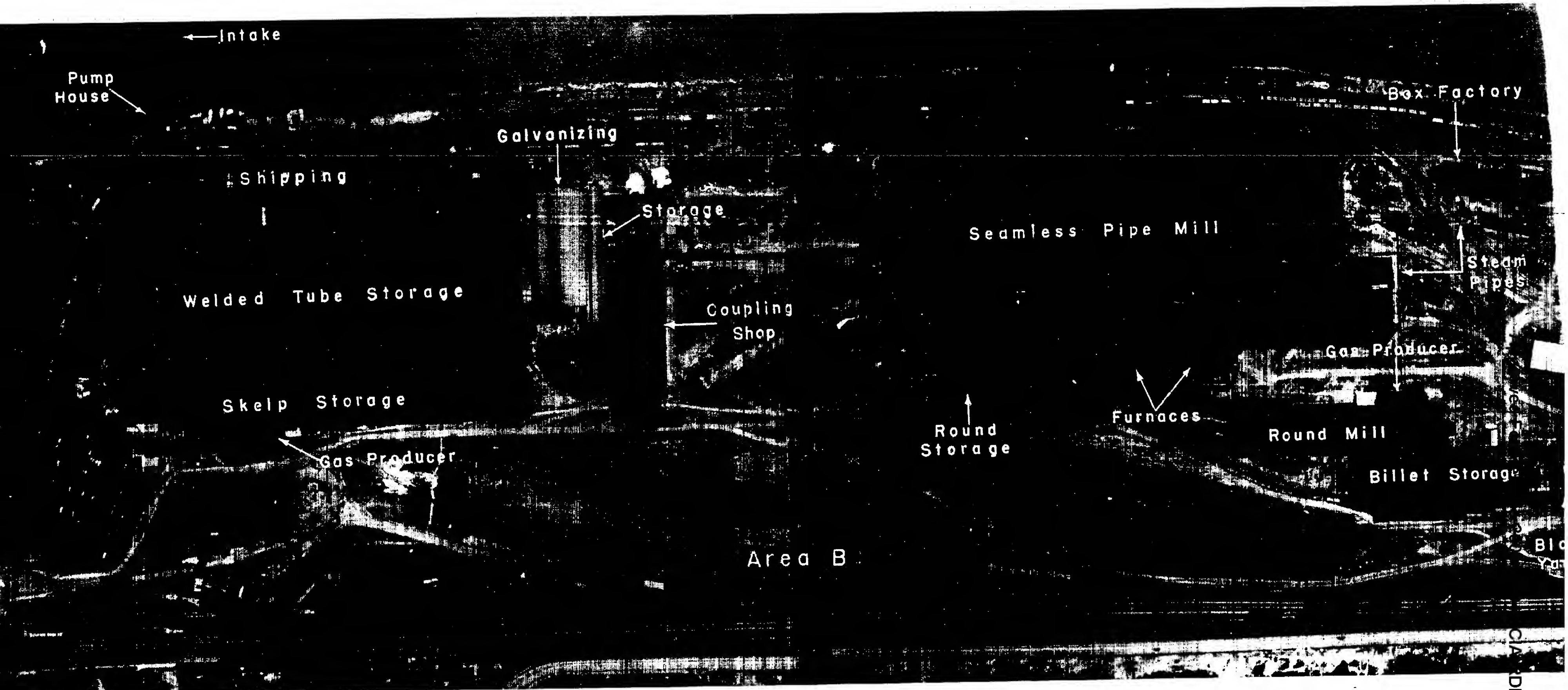
Portions of this plant are illustrated in the following photographs in Sections I - VII. Numbers refer to pages.

10-G	14-A	20-H	25-C	37-C
13-A	18-C	22-G	28-A	37-E
13-B	18-D	23-D	30-D	38-C
13-C	20-B	24-B	33-A	41-C
13-E	20-G	24-F	33-B	52-B
			33-E	53-A
			33-F	53-C
			37-B	53-G

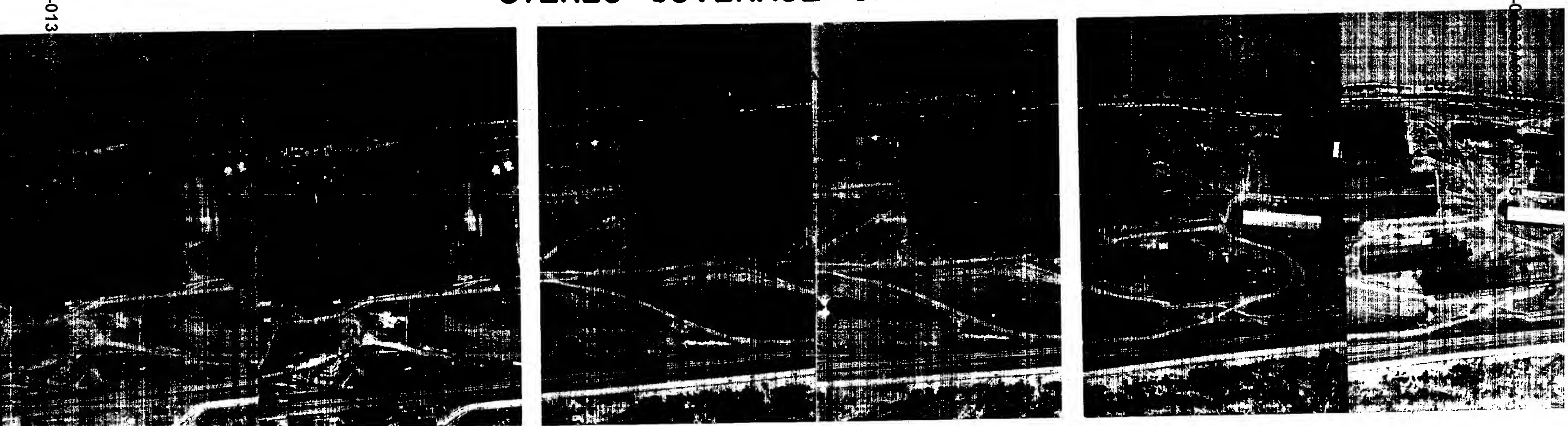


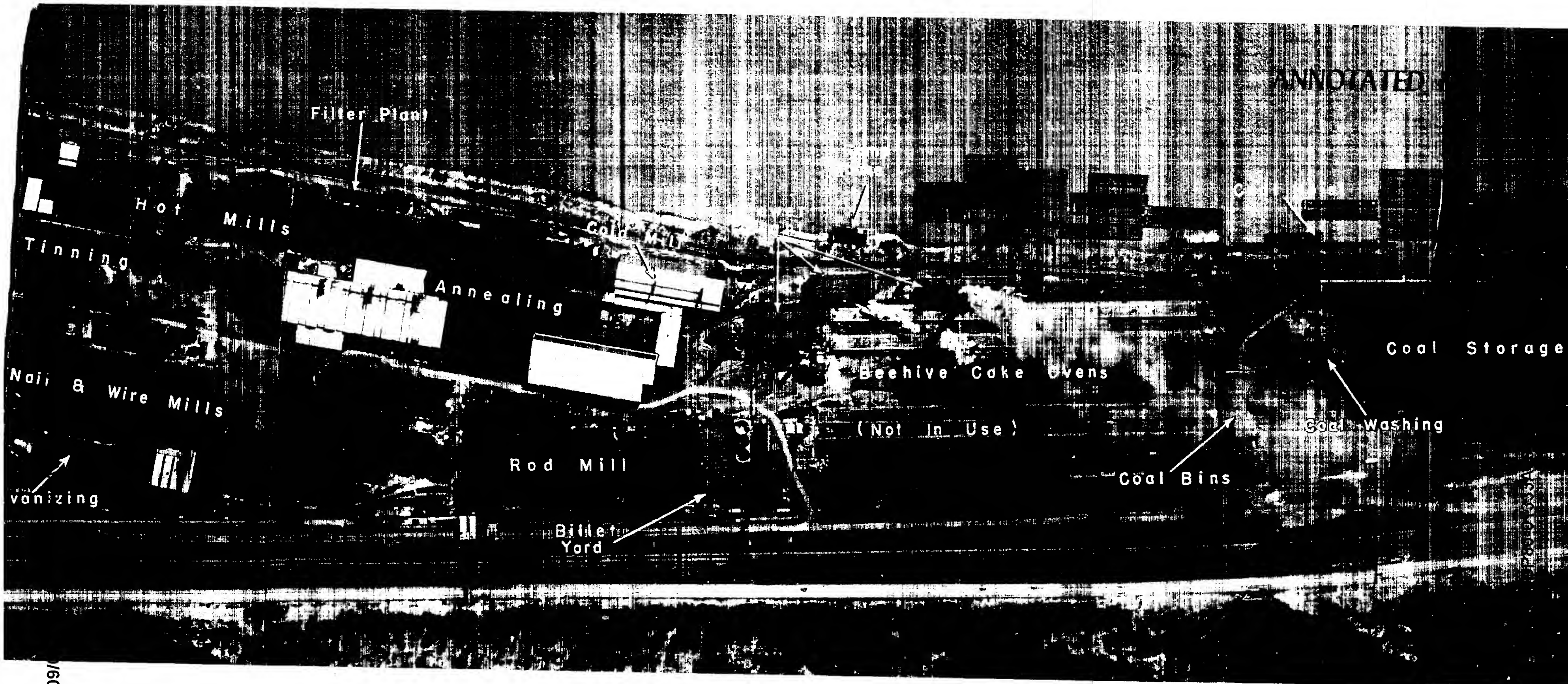




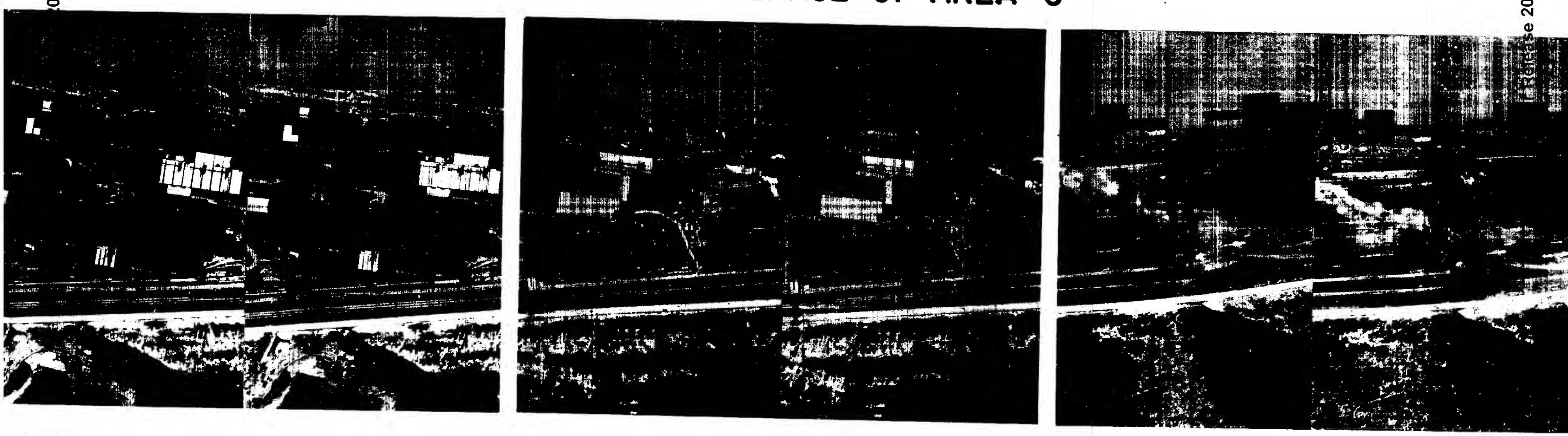


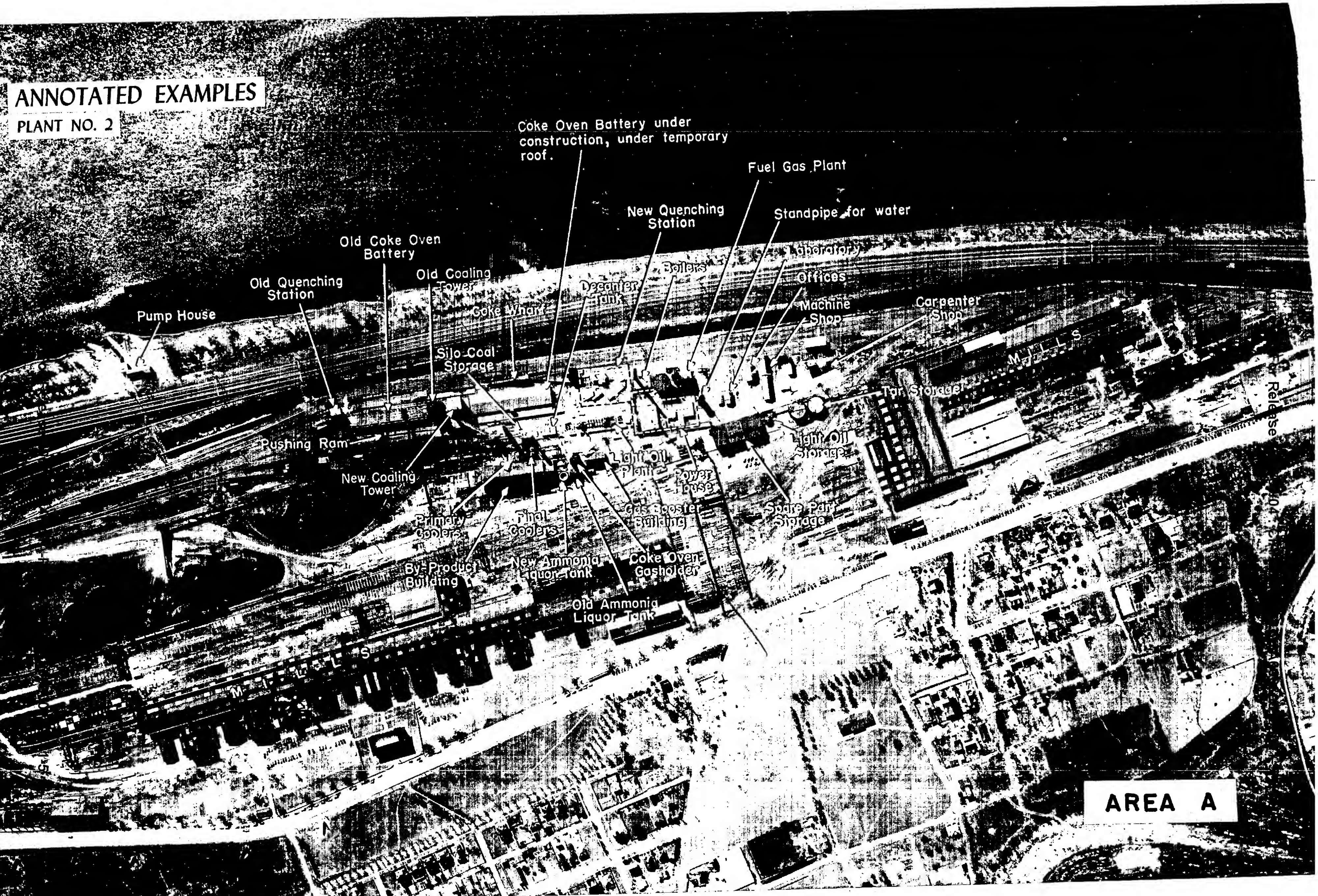
STEREO COVERAGE OF AREA B





STEREO COVERAGE OF AREA C



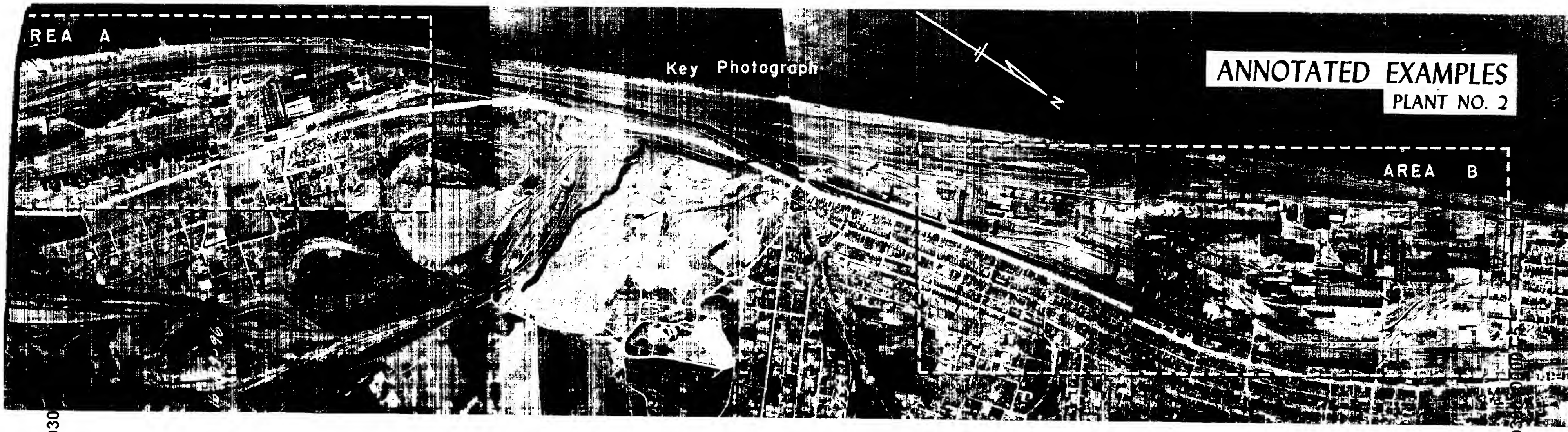


PLANT No. 2

EXAMPLE OF A SMALL INTEGRATED STEEL WORK

RESTRICTED

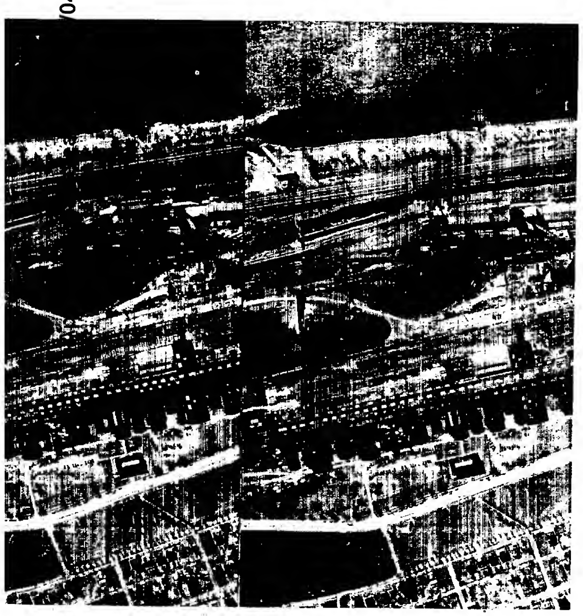
ANNOTATED EXAMPLES
PLANT NO. 2

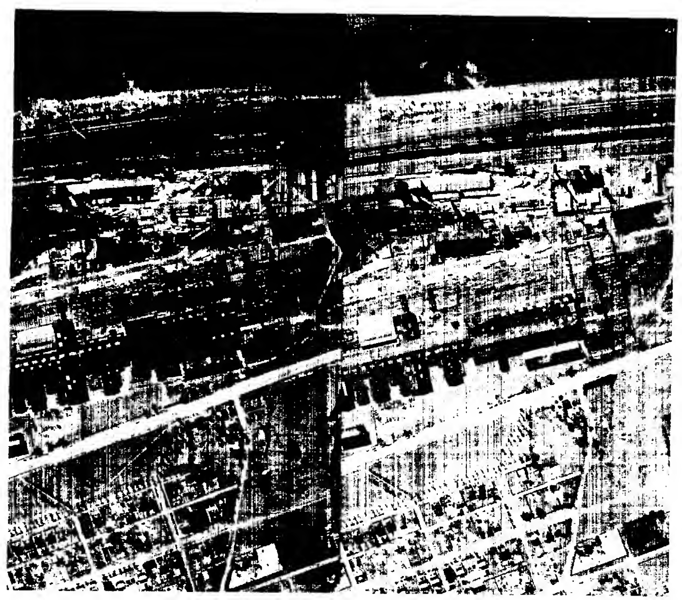


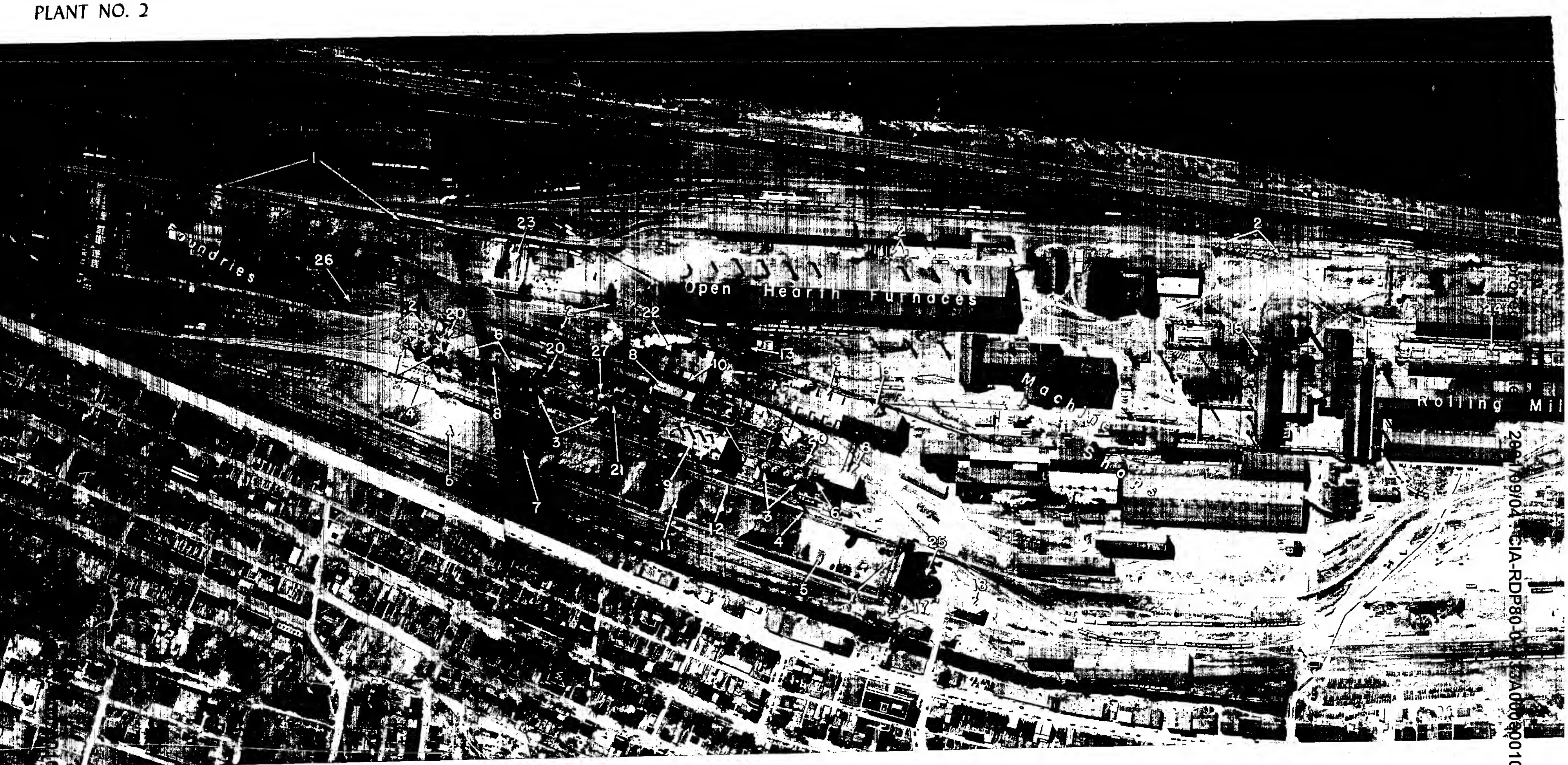
ortions of this plant are illustrated in detail in the following photographs of Sections I to VII. Numbers refer to pages:

4-A
5-E
8-A
9-E
10-A
10-B
10-E
11-E
12-B
16-B
17-C
17-D
19-A
19-B
19-C
22-B
22-C
23-A
23-B
23-E
24-C
25-G
37-H
41-D
41-E
46-C
47-A
48-D
53-B

STEREO COVERAGE OF AREA A ON OPPOSITE PAGE





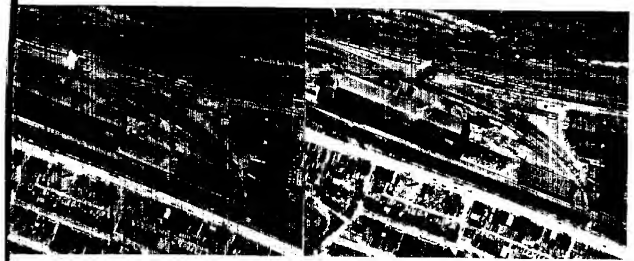


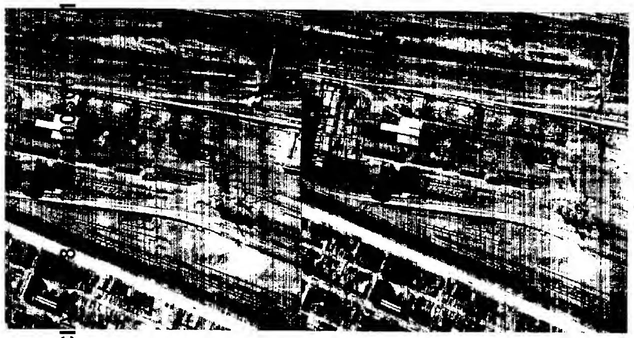
PLANT NO. 2 - AREA B

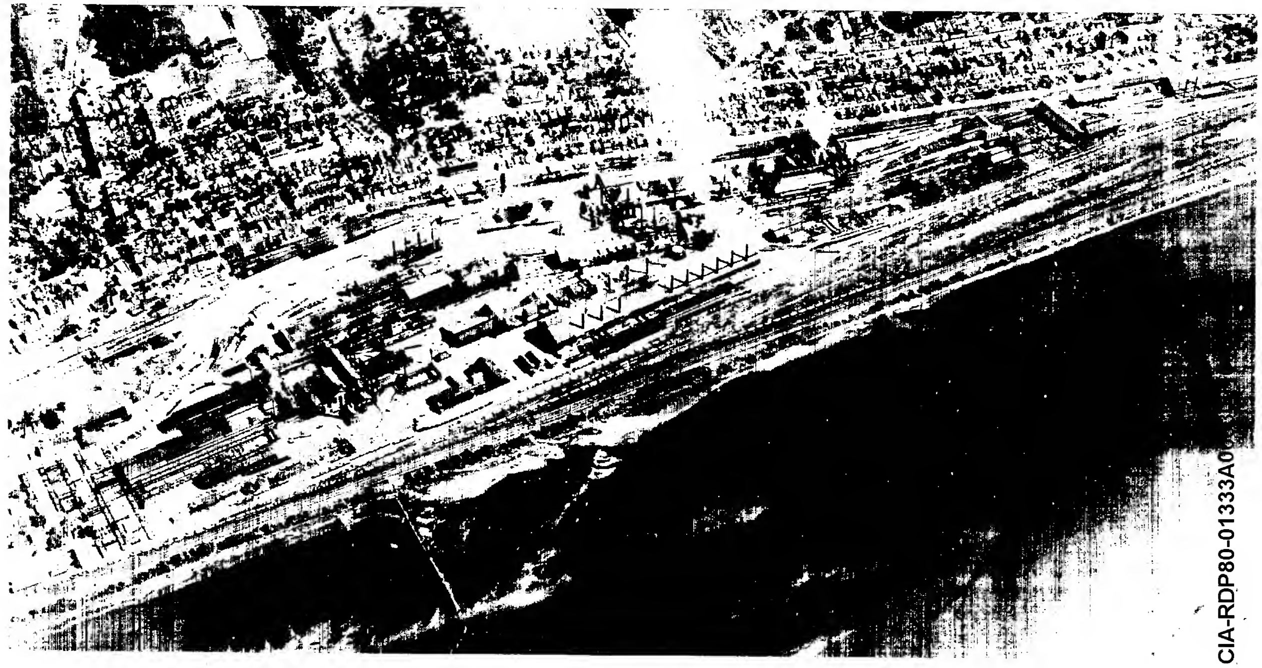
LEGEND

(1) Scrap storage
(2) Ladles
(3) Hot stoves
(4) Stock trestles and bins
(5) Lime and dolomite storage
(6) Blast furnaces
(7) Ore bridges
(8) Casting shed
(9) Power house
(10) Air intake
(11) Ore storage
(12) Loading trestles
(13) Blast furnace gas holder
(14) Soaking pits
(15) Foundry
(16) Forge shops
(17) Ore handling power substation
(18) Offices
(19) Machine shop
(20) Dust catcher
(21) Gas cleaning
(22) Blower house
(23) Pig casting machine
(24) Rail storage
(25) Coke storage
(26) Molds
(27) Precipitators
(28) Ladle repair shop

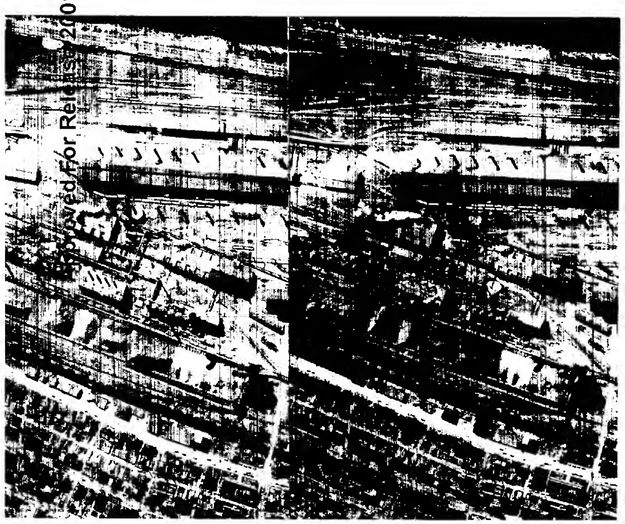
RESTRICTED

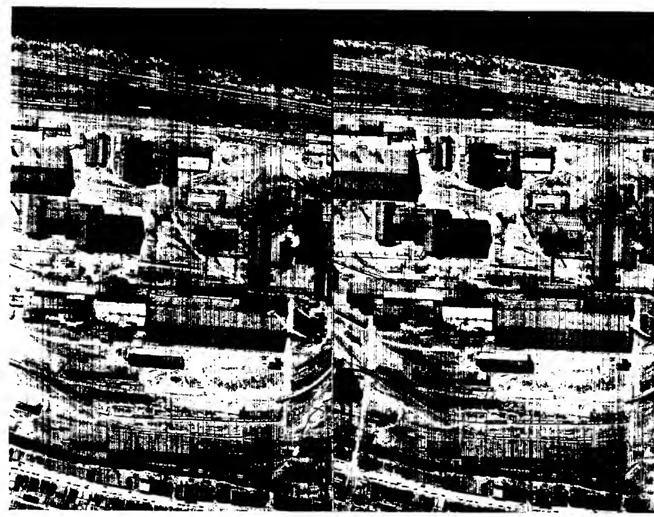


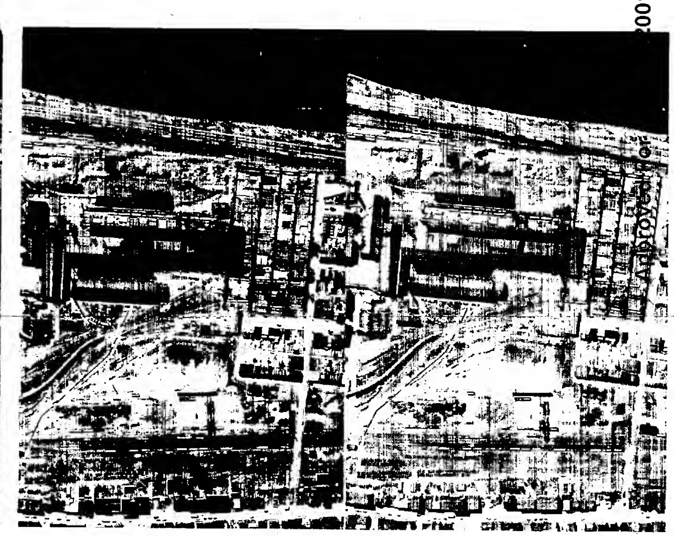




STEREO COVERAGE OF AREA B ON OPPOSITE PAGE



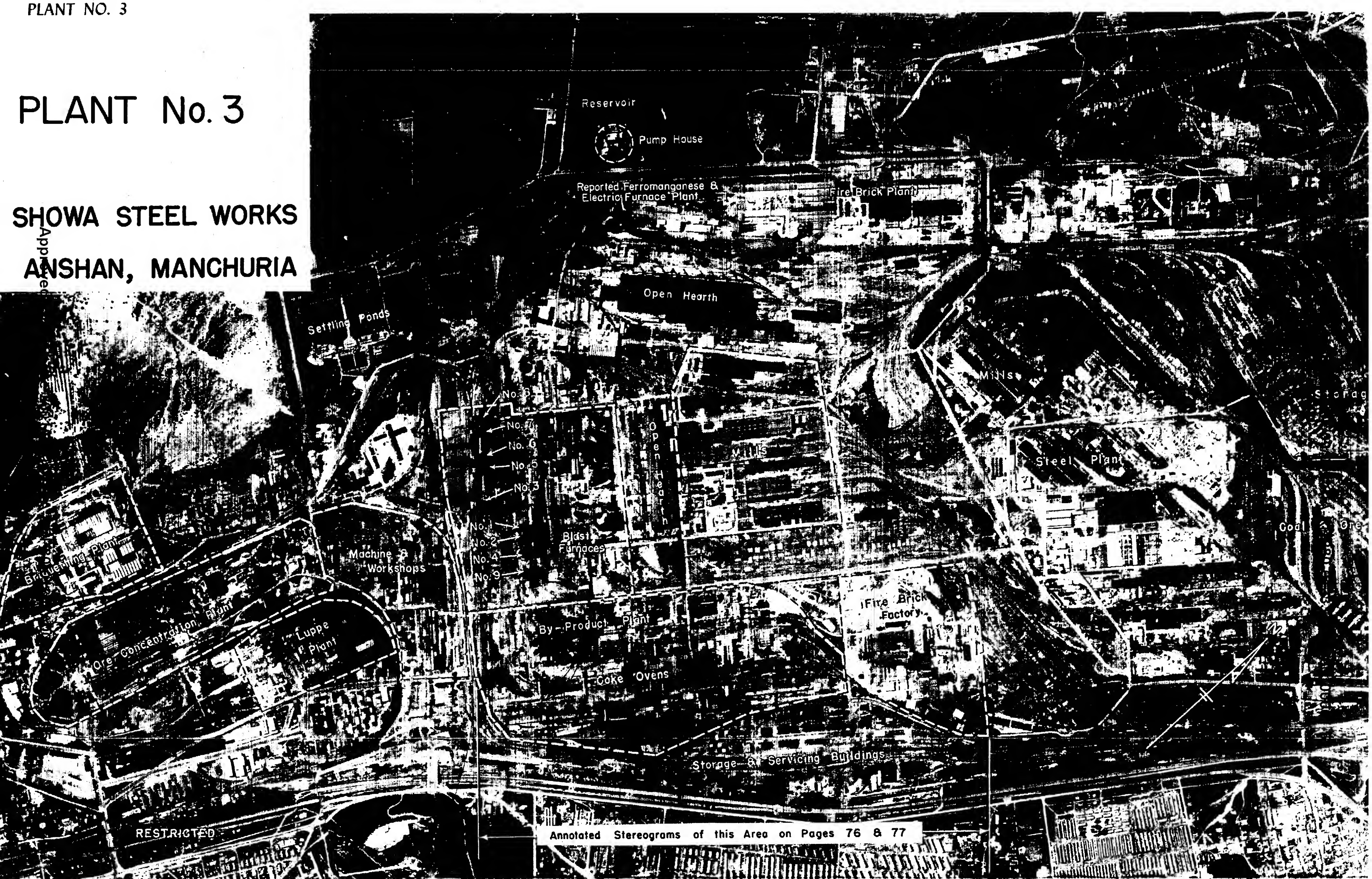




PLANT No. 3

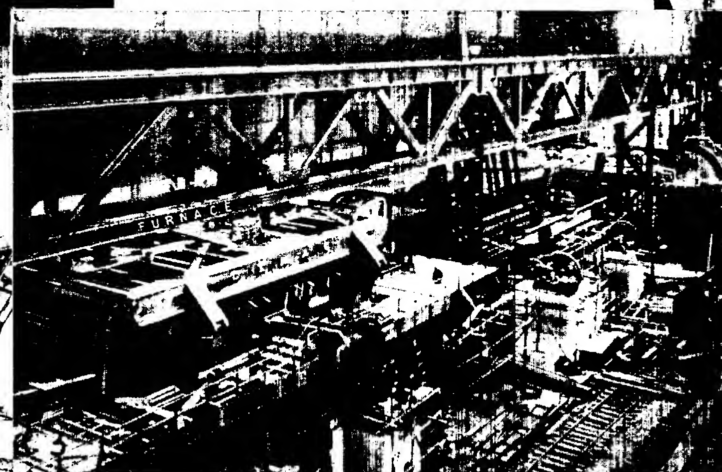
SHOWA STEEL WORKS

ANSHAN, MANCHURIA

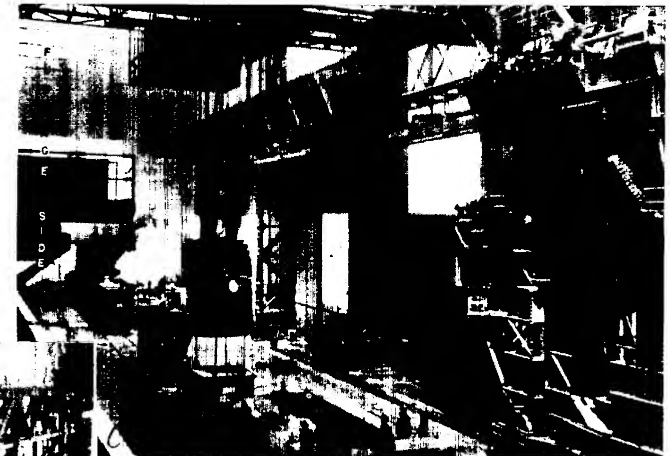


GROUND VIEWS

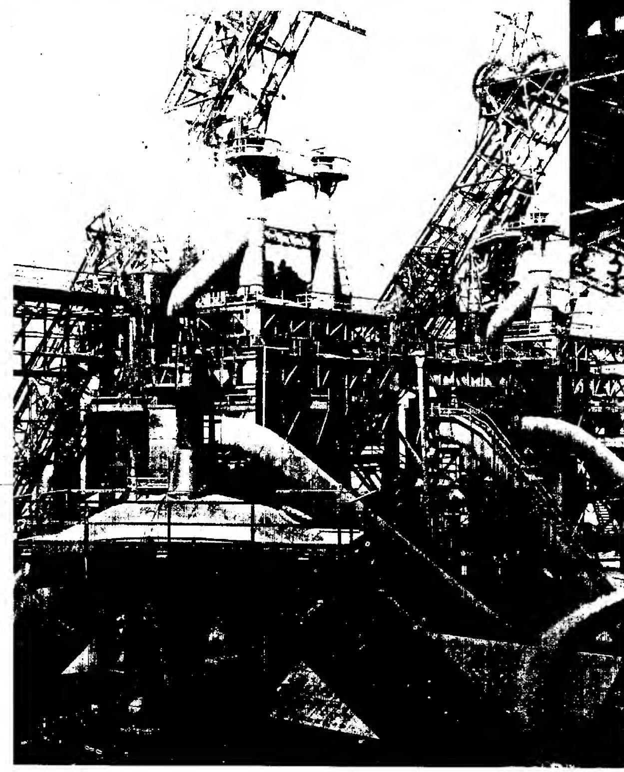
TAPPING AN OPEN HEARTH FURNACE



OPEN HEARTH FURNACE UNDER CONSTRUCTION



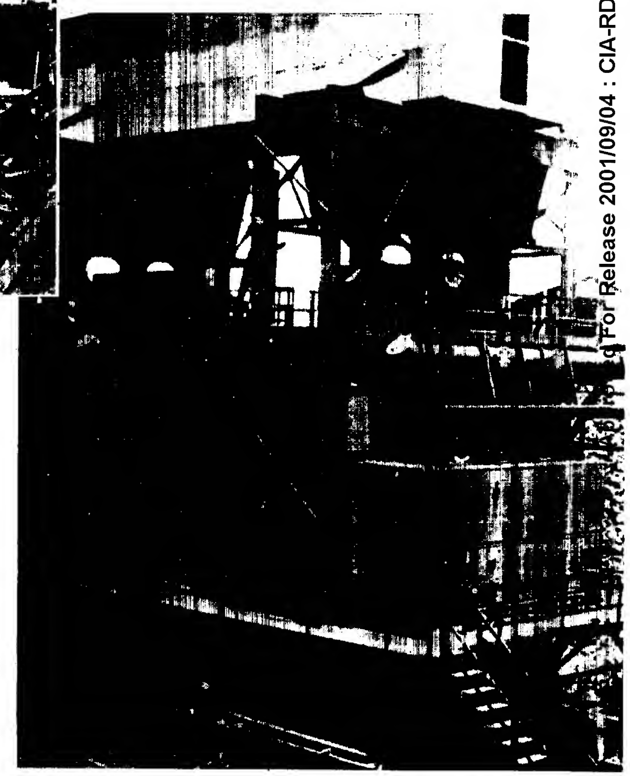
CASTING PIT OF SAME OPEN HEARTH FURNACE:



UPPER PORTIONS OF NO. 1 AND NO. 2 BLAST FURNACES

SHOWA STEEL WORKS

ANSHAN, MANCHURIA



ORE ROASTING FURNACE UNIT

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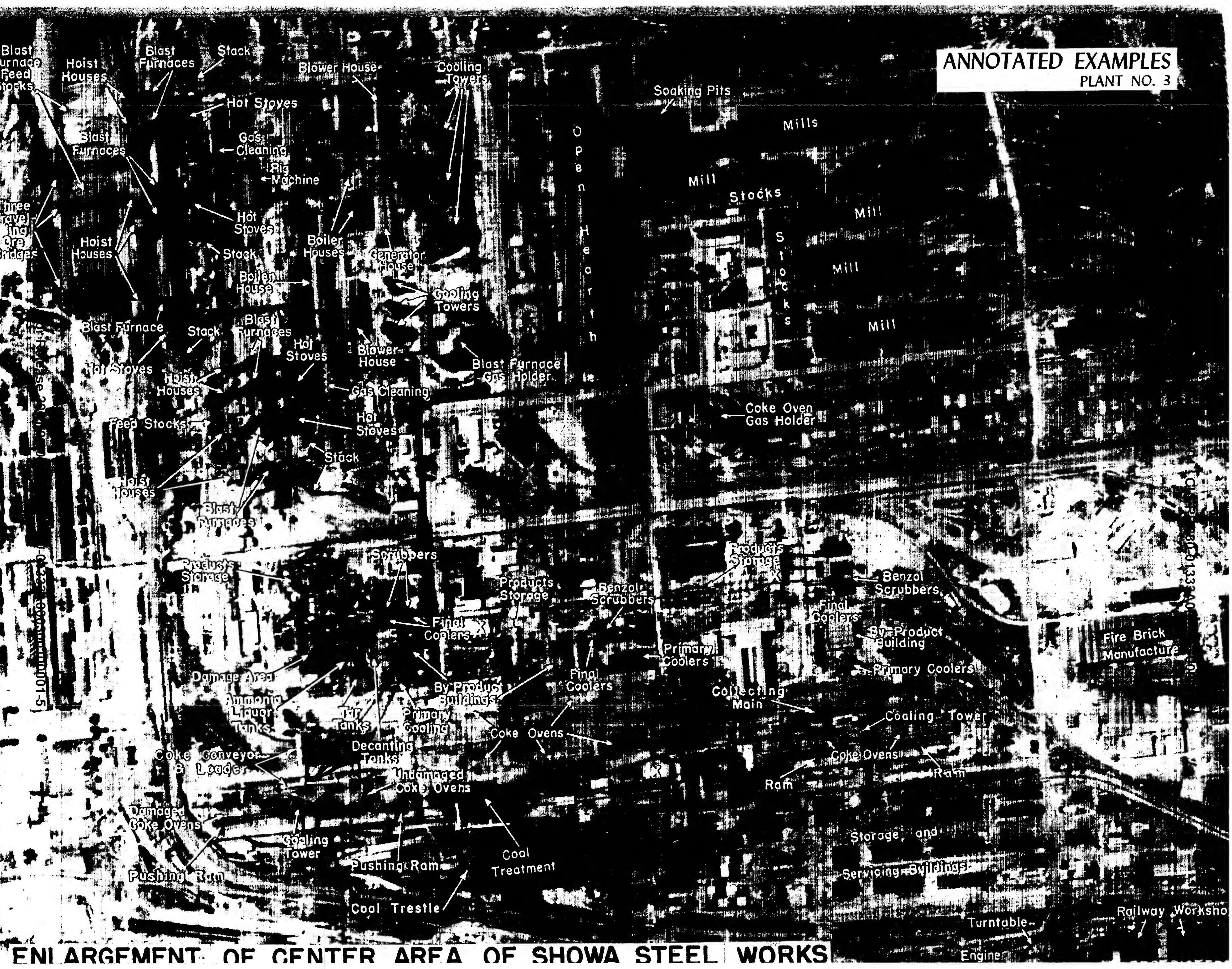
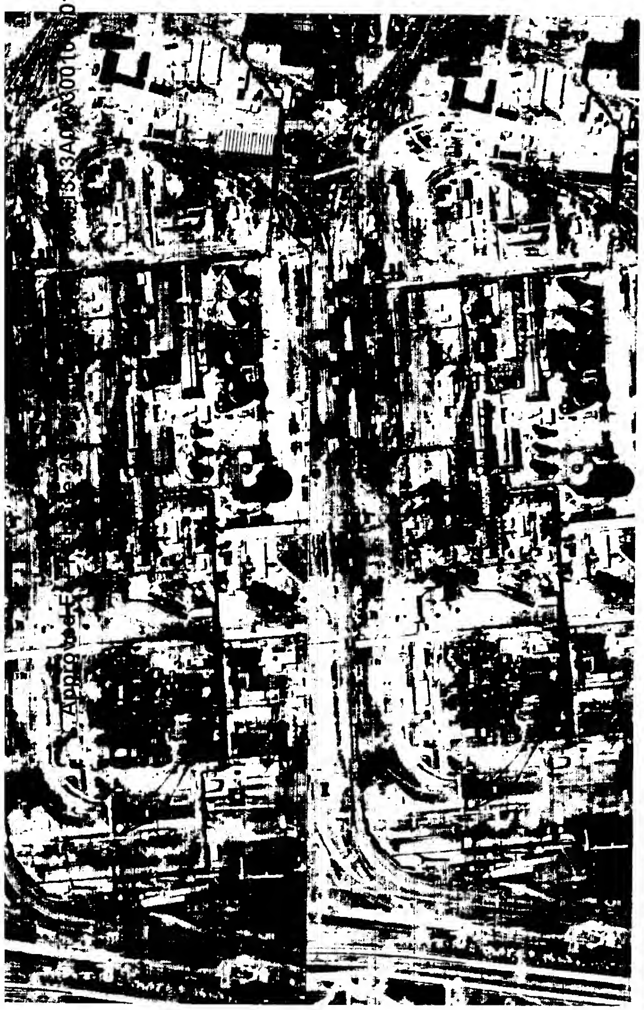
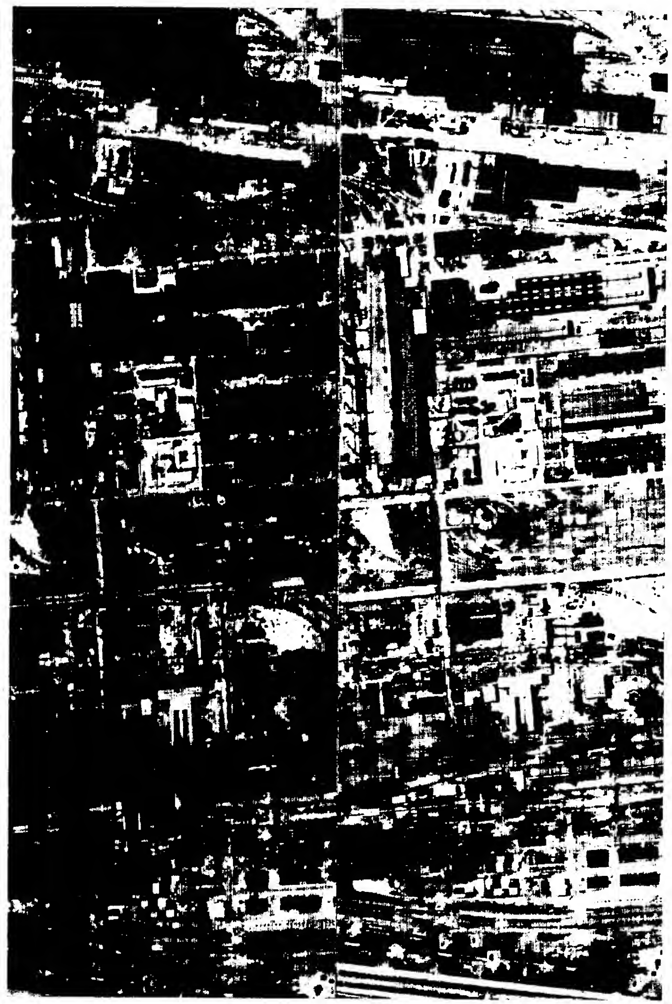


ENLARGEMENT OF CENTER AREA OF SHOWA STEEL WORKS

STEREO COVERAGE OF MOSAIC ON OPPOSITE PAGE

Buildings marked with an "x" on the opposite mosaic may be considered as possible boiler or power houses, but cannot be positively identified. Portions of this plant are illustrated in detail in the following photographs of Sections I to VII. Numbers refer to pages: 17-A, 17-B, 18-B, 20-F, 26-B, 30-B, 54-B, 59-A, 62-A, 64-B.

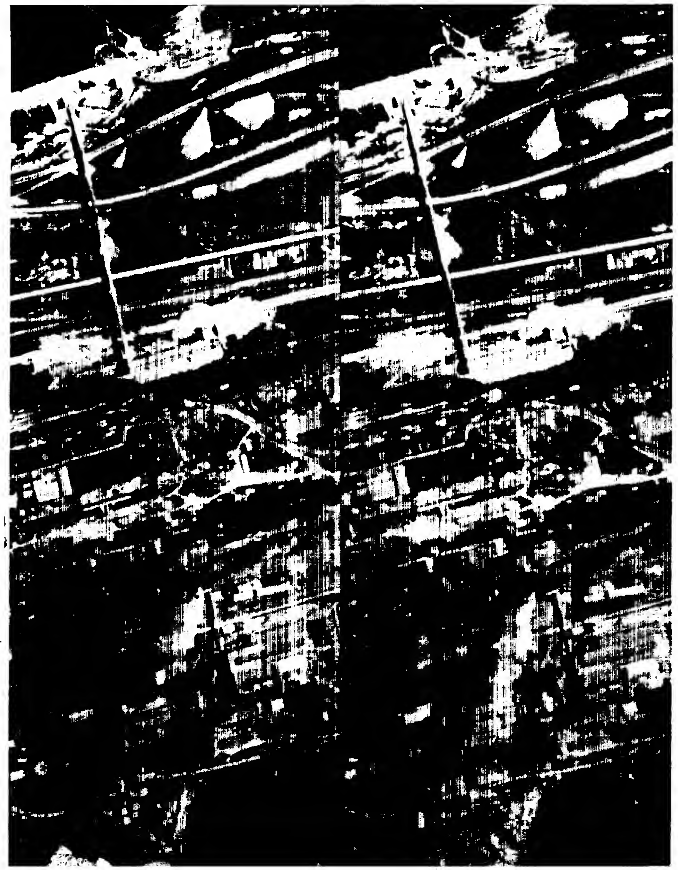


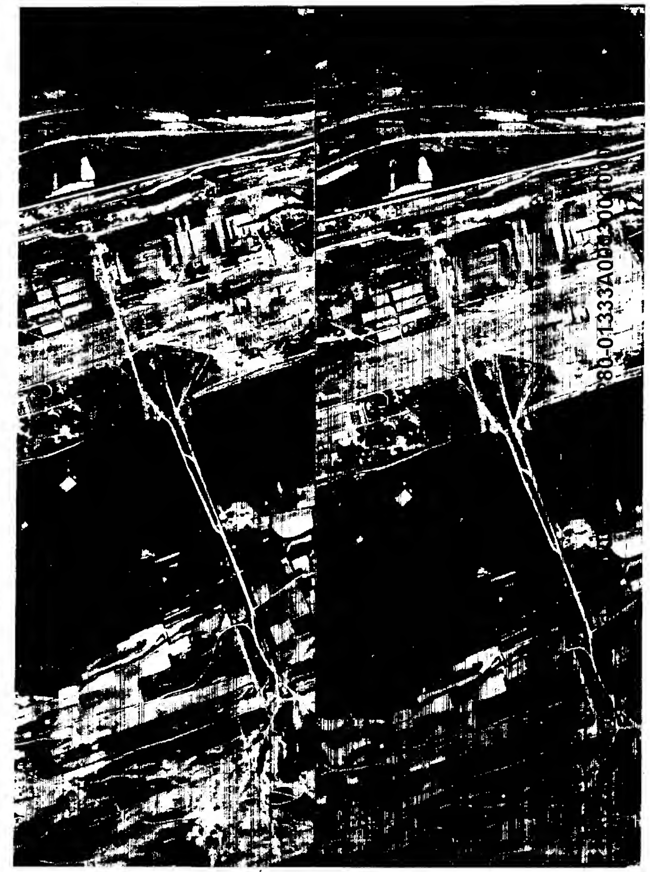


PLANT No. 4

PENHSIHU IRON WORKS

PENHSIHU, MANCHURIA



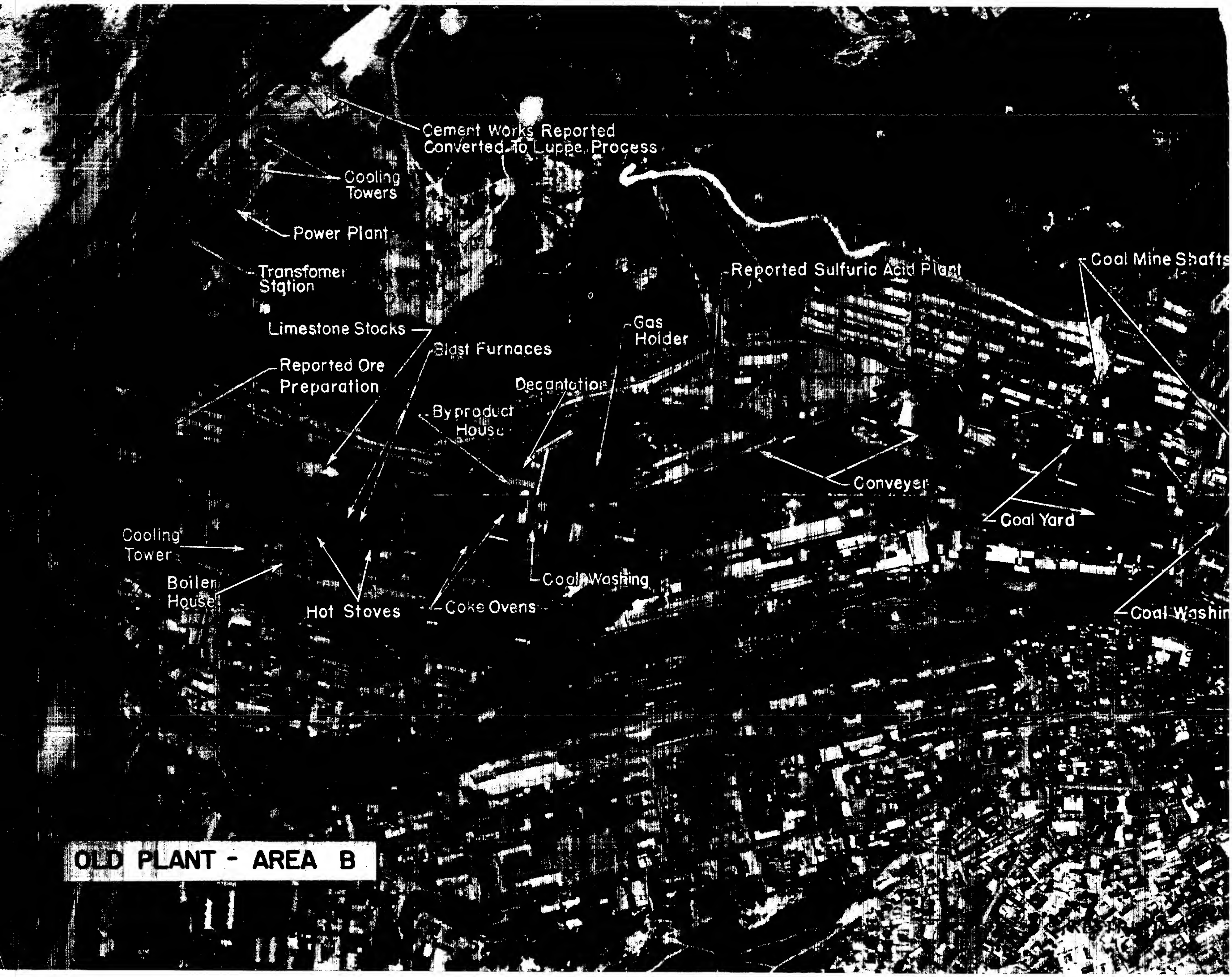


STEREO COVERAGE

NEW PLANT

The building annotated "Steel Works" on the photograph on opposite page is reported to have been originally laid out as an open hearth building. It is considered probable that forced draft steel furnaces or smelting furnaces of some type are installed here.

Another stereogram of this plant is on page 58.

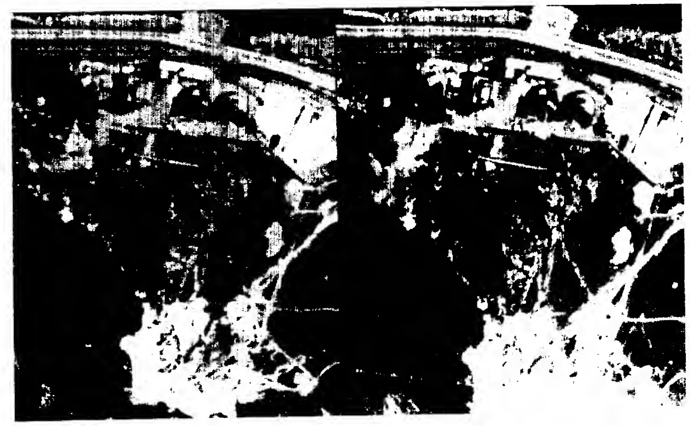


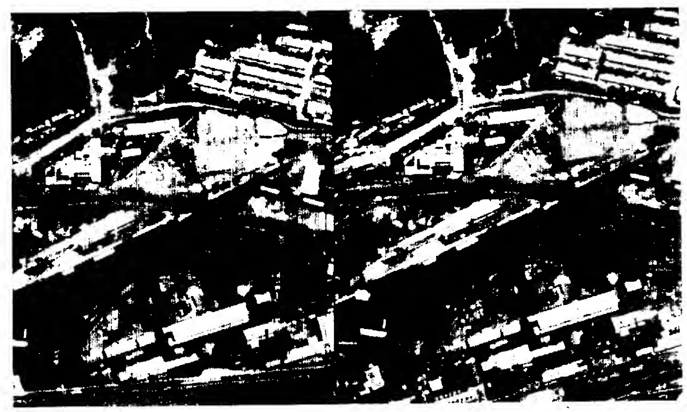
OLD PLANT - AREA B

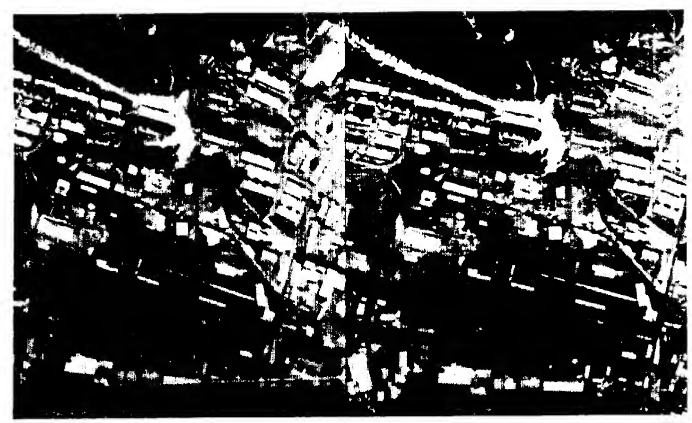
STEREO COVERAGE

OLD PLANT

Additional photographs of this plant: 54-C and 57-D.







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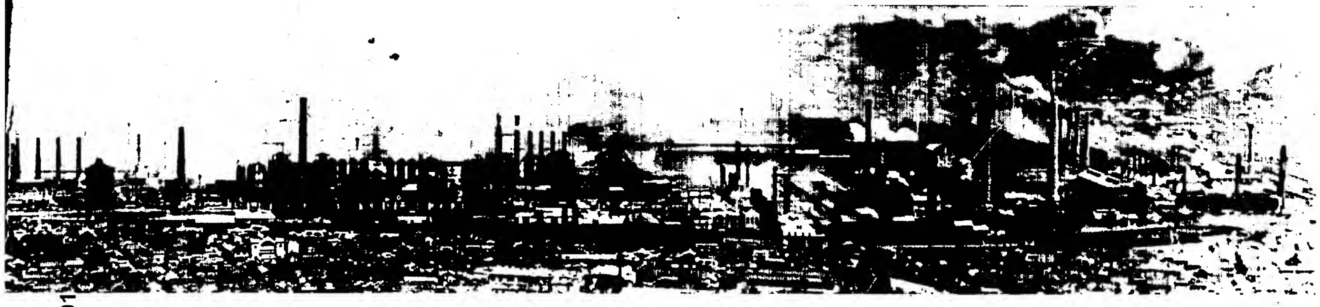
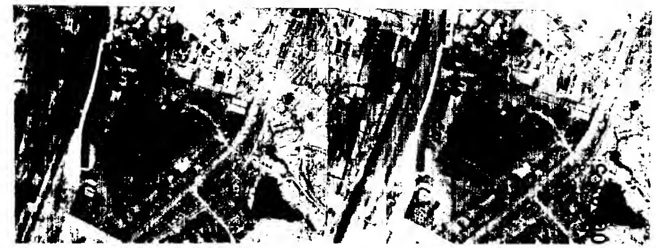
PLANT No. 5 JAPAN IRON WORKS, YAWATA, KYUSHU

ANNOTATED EXAMPLES

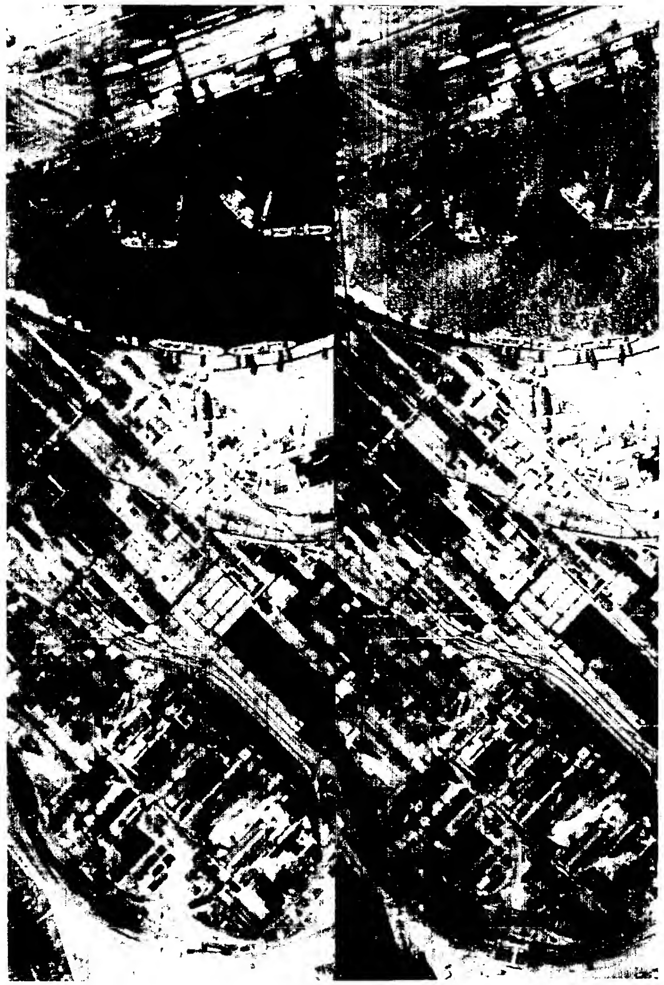
PLANT NO. 5

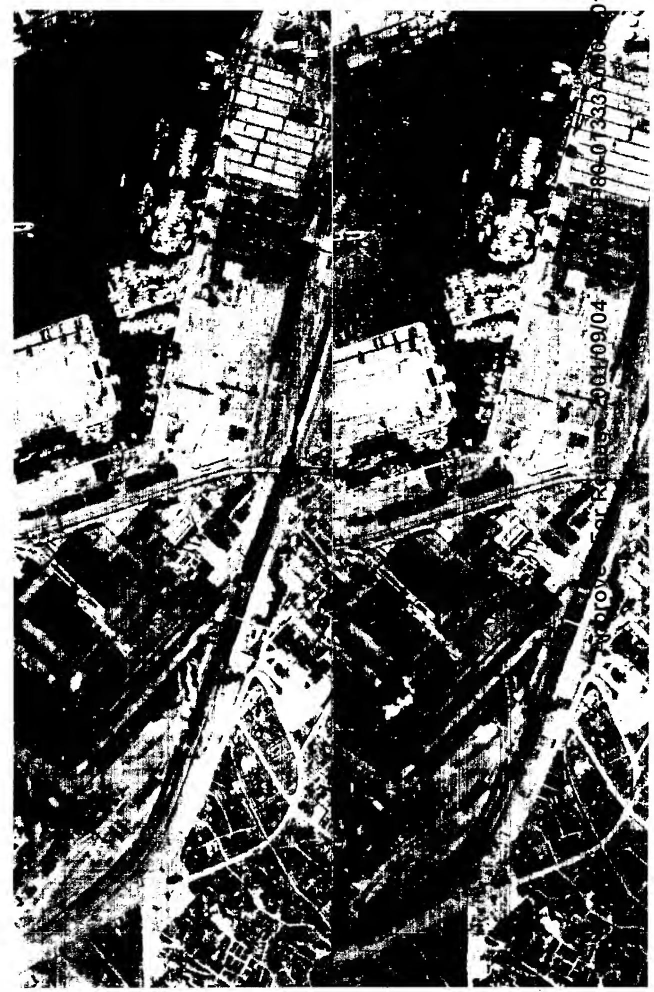
Building annotated "Z" in the photograph opposite is considered as probably containing some crucible or other steel furnaces, although not so reported. In this event the adjoining building annotated "Reported Crucible Steel" might be a furnace repair shop.





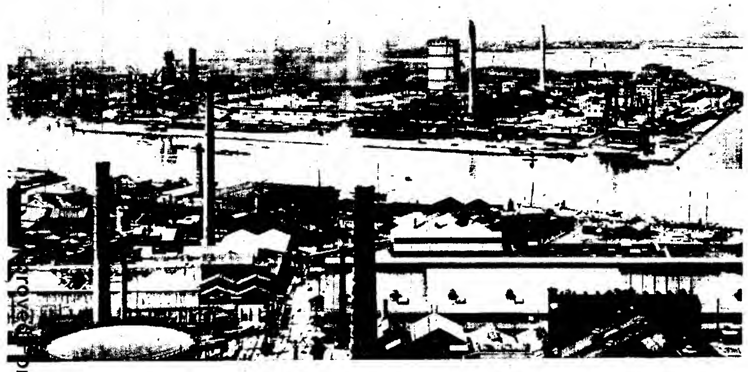
STEREO COVERAGE OF OLD PLANT AREA





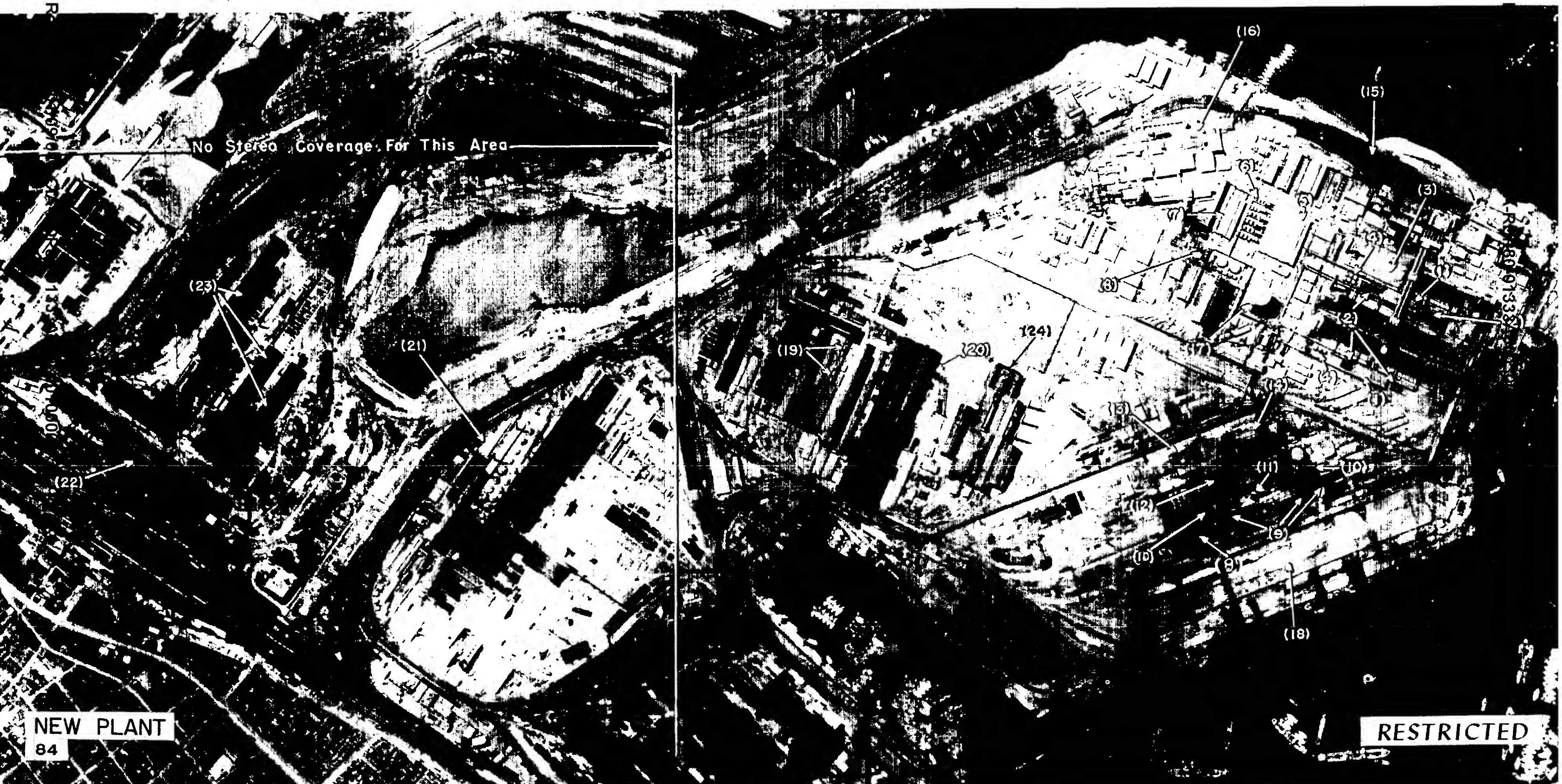
ANNOTATED EXAMPLES

PLANT NO. 5



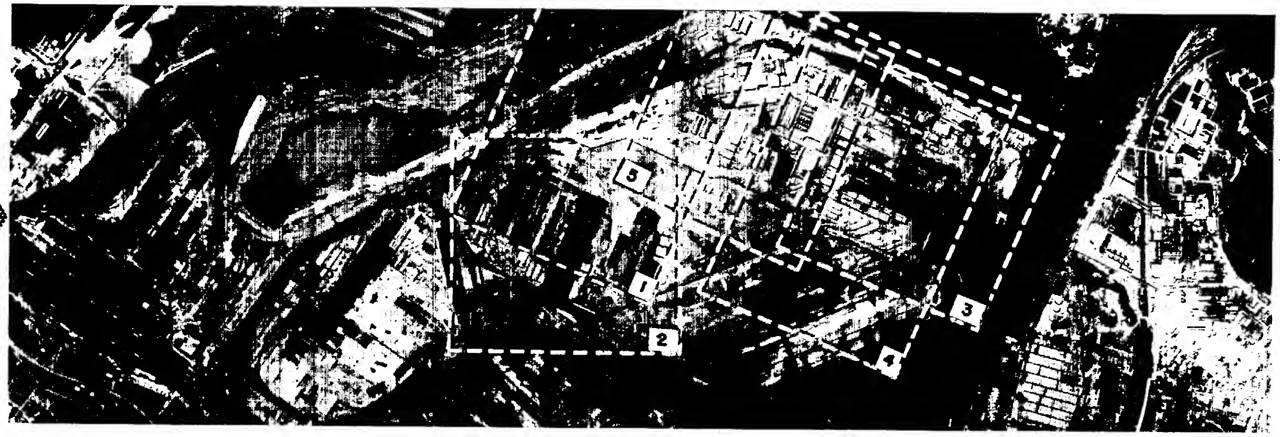
LEGEND

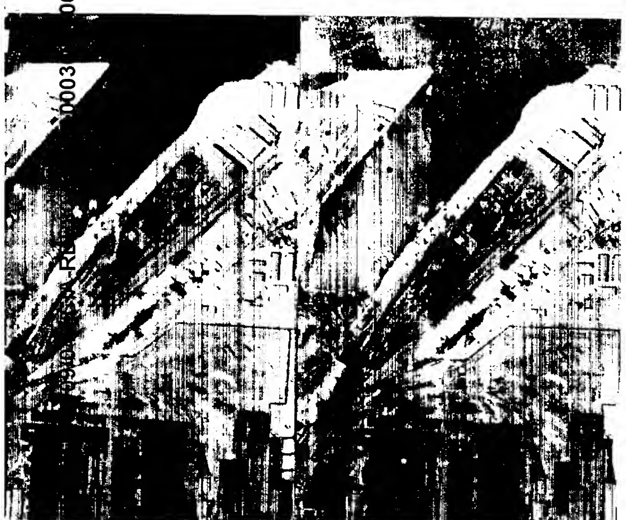
1. Exhausters
2. Primary coolers
3. Foundations for new coke ovens
4. Decantation tanks
5. Ammonium sulfate
6. Final coolers
7. Benzol house
8. Products storage
9. Blast furnaces
10. Hot stoves
11. Water tower
12. Gas cleaning
13. Reported power house
14. Blower house
15. Coal trestles
16. Possible fertilizer plant
17. Gas holder
18. Blast furnace feed stocks
19. Six possible Bessemers
20. Possible mill buildings
21. Refractory brick plant
22. Open hearth furnaces
23. Mill buildings
24. Unidentified building under construction



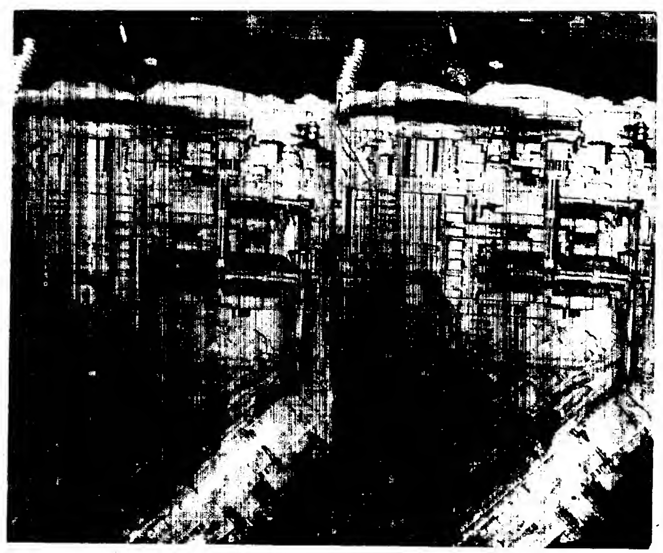
COVERAGE OF NEW PLANT

KEY PHOTO TO STEREOS BELOW





Stereograms Nos. 1 and 2 show complete coverage of the same group of installations.



Portions of this plant are illustrated in detail in the following photographs in Section I to VII: 7-A, 14-B, 22-E, 62-F, 62-G, 63-A, 63-B, 64-A, 65. The ore cranes and pier are shown in stereograms of the old plant on page 83.

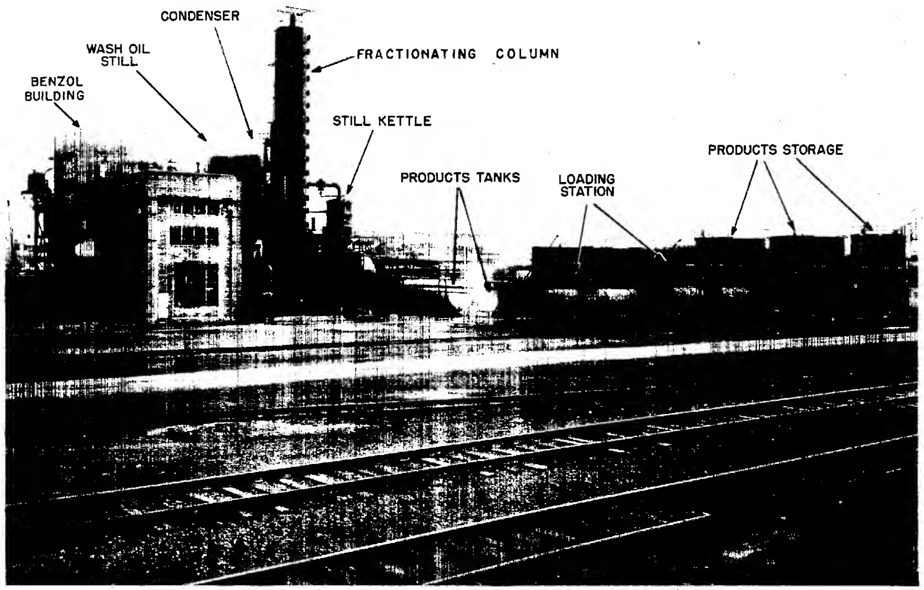
BYPRODUCT PLANTS

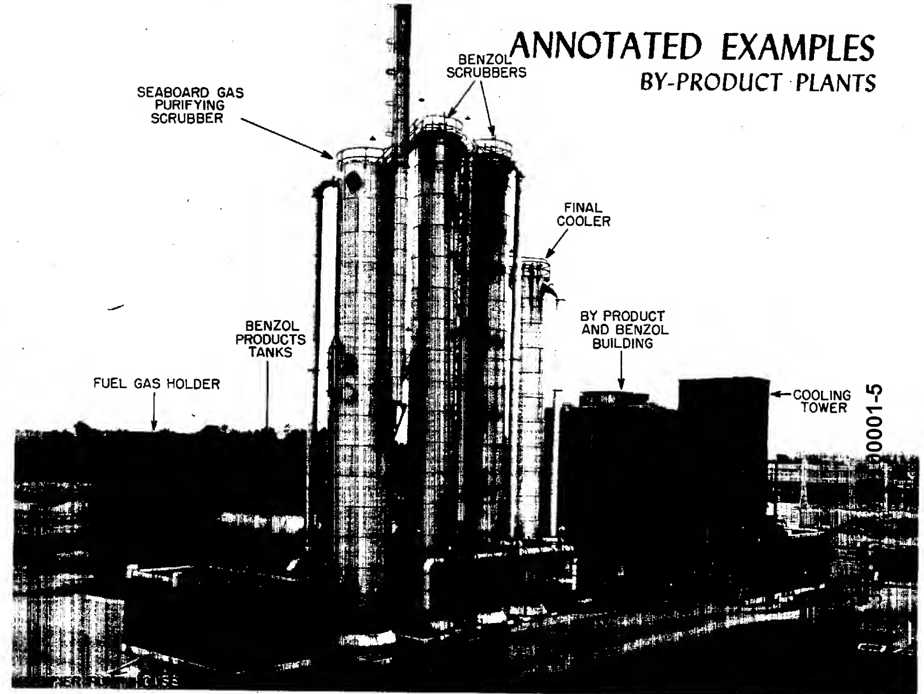
PART I

L E G E N D

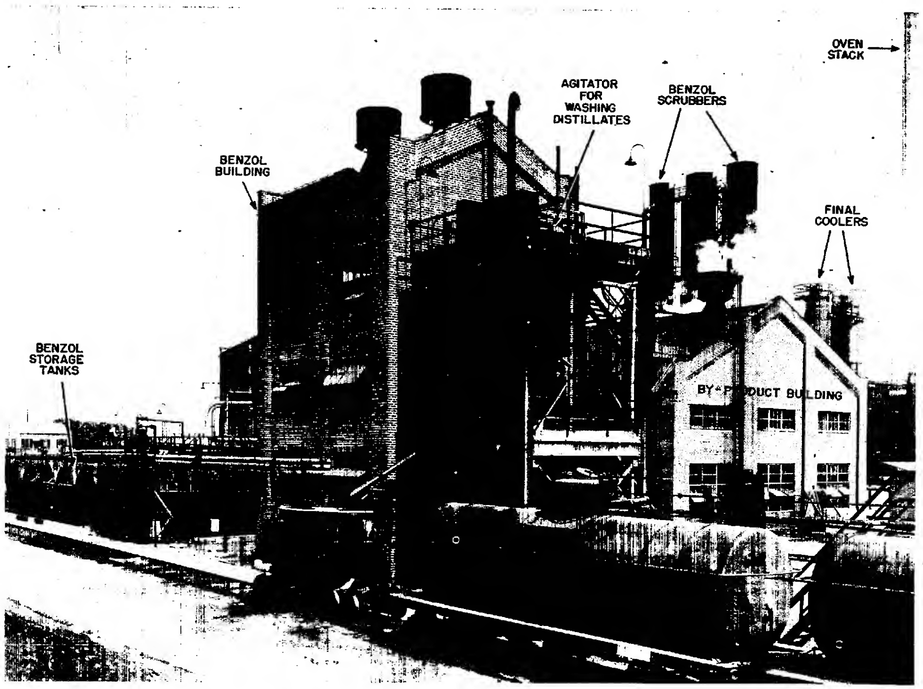
(1) Sodium phenolate storage
(2) Tar distillation plant
(3) Caustic soda storage
(4) Sodium phenolate tower
(5) Sulfuric acid storage
(6) Liquor flushing pumps & ammonia stills
(7) Chemical oil refining
(8) Chemical fire fighting pump house
(9) Employees wash rooms etc.
(10) Ammonia liquor storage
(11) Decanting tanks
(12) Machine shop
(13) Tar storage
(14) Workshops
(15) Naphthalene pans & oil spillage recovery
(16) Oil transit dock
(17) Three 100,000 gallon benzol tanks
(18) Non-volatile light oil storage
(19) Six 50,000 gallon light oil products tanks
(20) Benzol purification by freezing
(21) Benzol distillation
(22) Wash oil still
(23) Light oil stills
(24) Boiler house stacks
(25) Cooling tower (Final cooler circulating water)
(26) Boiler house
(27) Boiler ash pit
(28) Byproduct building & ammonium sulfate storage
(29) Electrical sub-station
(30) Primary coolers
(31) Pyridine recovery
(32) Ovens fuel gasholder
(33) Pump house
(34) Naphthalene recovery from final cooler sump
(35) Two final coolers & four benzol towers
(36) Residual tar and tar acid oil storage
(37) Tar distillation
(38) Water cooling system
(39) Distillation columns

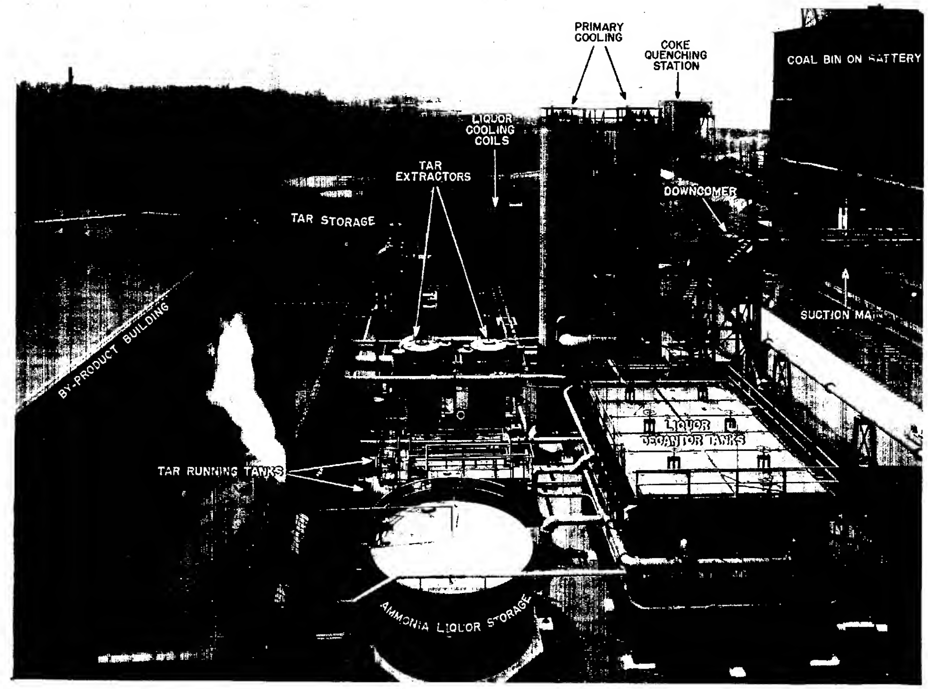
RESTRICTED





BYPRODUCT PLANTS - PART 2 (MISCELLANEOUS)





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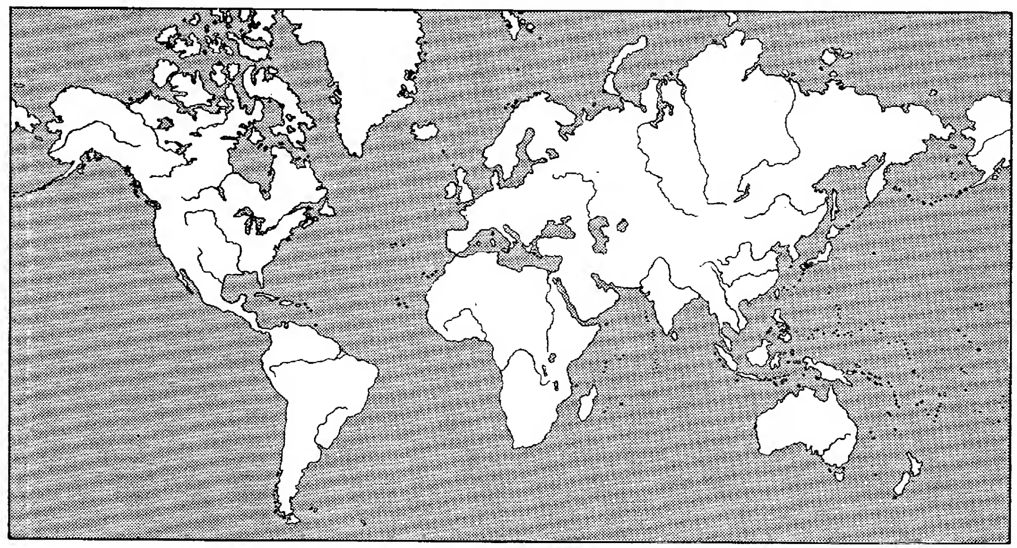
SECTION IX

MAPS



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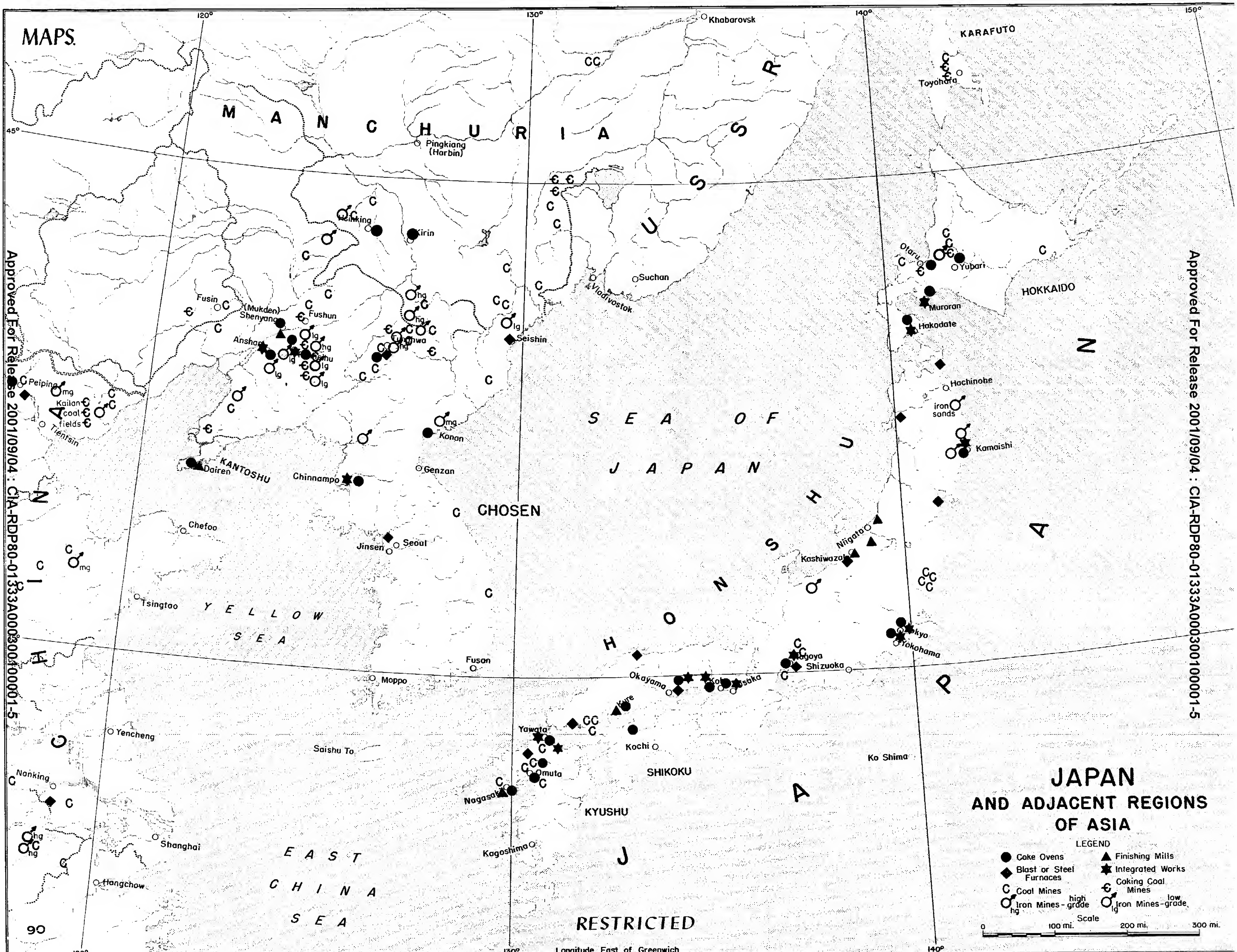

RESTRICTED

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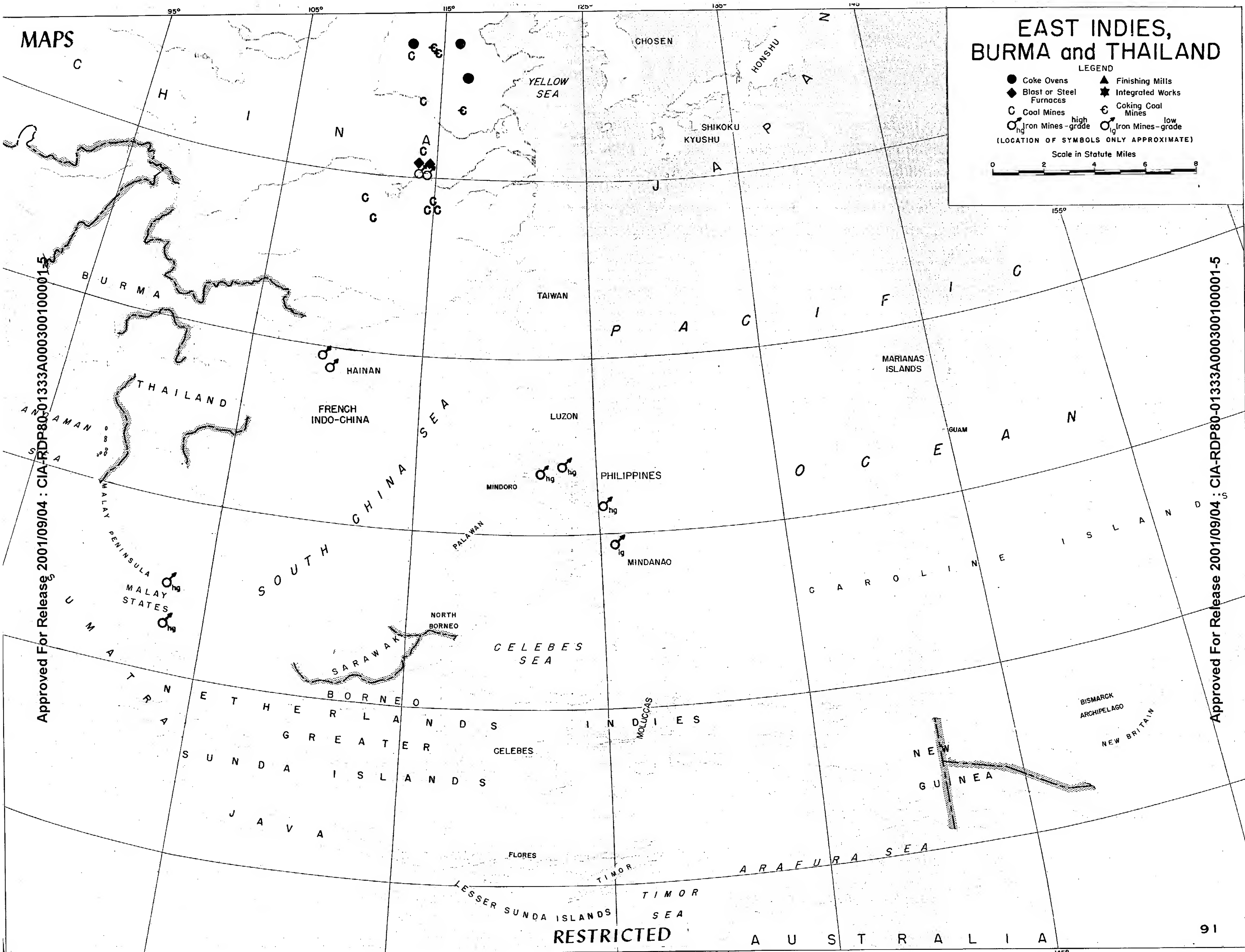

RESTRICTED

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INDEX

(SMALL LETTERS FOLLOWING PAGE NUMBERS INDICATE COLUMN; CAPITAL LETTERS REFER TO AN ILLUSTRATION)

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